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POPULAR ASTRONOMY

PLAINLY WORDED AND LARGELY UNTECHNICAL IN LANGUAGE. AMPLY ILLUSTRATED.

ISSUED MONTHLY EXCEPT JULY AND SEPTEMBER.
ANNUAL VOLUME (10 NUMBERS).

VOL. XII.

1904.

EDITORS:
WILLIAM W. PAYNE, H. C. WILSON.

OFFICE OF PUBLICATION:
GOODSELL OBSERVATORY OF CARLETON COLLEGE,
NORTHFIELD, MINNESOTA,
U. S. A.

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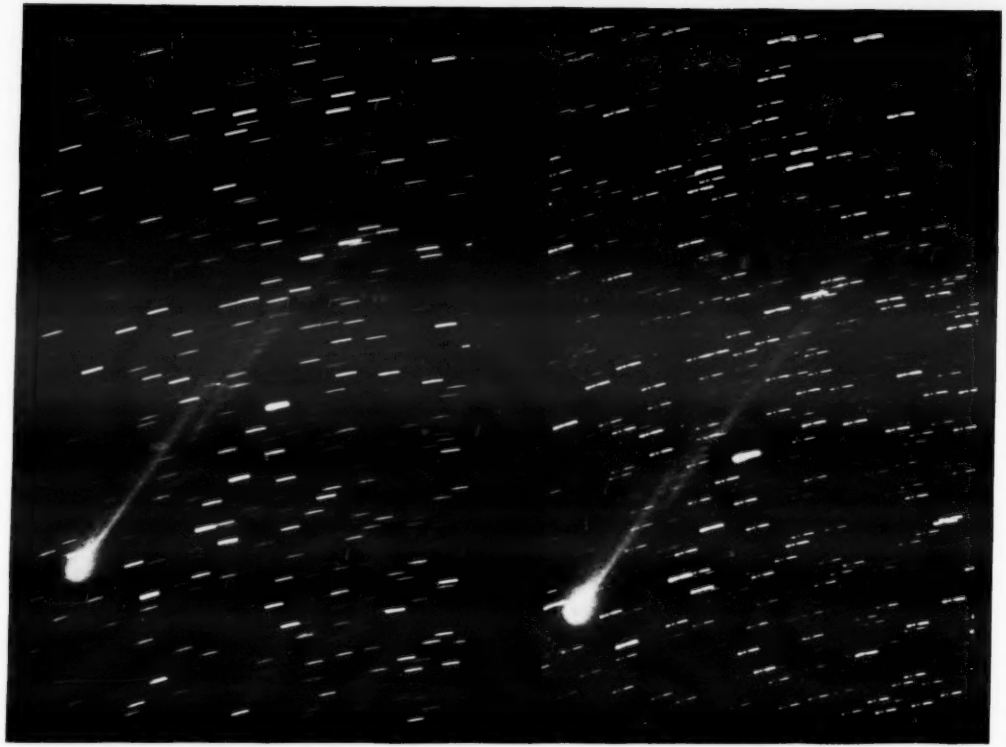
PLATE I



$17^h\ 59^m - 20^h\ 29^m$ G. M. T. $14^h\ 57^m - 17^h\ 34^m$ G. M. T.

BORRELLY'S COMET

1903 JULY 24th

The left hand photograph was made by R. J. Wallace.
Reproductions of the same plates were published in the Astrophysical Journal Oct. 1903.

Popular Astronomy.

Vol. XII No. 1. JANUARY, 1904. Whole No. 111.

SOME PECULIARITIES OF COMETS' TAILS AND THEIR PROBABLE EXPLANATION.

E. E. BARNARD.

(Read before the Chicago Meeting of the National Academy, 1903 Nov. 18.)

Before the application of photography to the investigation of cometary phenomena the study of these bodies was beset with many difficulties. In fact most of the changing phenomena of the tails of comets were then wholly unknown and, hence, their study impossible.

The study of the physical condition of comets' tails may be said to have had its beginning in the past ten or twelve years. In that interval though no great comet has appeared, the photographic plate has faithfully portrayed some of the most extraordinary phenomena such as have to a great extent revolutionized our ideas of these erratic bodies. This, too, has occurred in the case of comets which with the older method of observing would have promised little or nothing of interest.

The remarkable phenomena presented by Swift's comet of 1892 were the beginning of these revelations. These were followed by similar appearances in Rordame's comet of 1893 as photographed by Professor Hussey.

But a new series of phenomena appeared in Brook's comet of 1893 which were suggestive of a wholly different explanation to those of Swift's and Rordame's comets. They suggested an outside influence foreign to the comet itself and of an extremely important nature.

The last comet sufficiently active to produce anomalous features was Borrelly's of the present year. This object, though it failed to fulfil the promises of a spectacular naked eye affair, showed a remarkable change in its tail on July 24 which will perhaps throw more light on cometary phenomena than any other comet has yet done. Though, unlike Brooks' comet of 1893, it suggested no outside influence, it yet presented an appearance that seems to offer itself to a satisfactory explanation, and which leads to a definite knowledge of the motion of the particles com-

Reproductions of the same plates were published in the Astrophysical Journal Oct. 1903.

posing the tail, and of the interval of luminosity of these particles when free from the comet.

In the case of Swift's comet a large mass of matter—several times larger than the head of the comet—was shown in the tail drifting back from the head. This seemed to be due to the separation of an unusually large portion of the cometary matter by the disruptive and repellant force of the Sun. Perhaps the most remarkable part of this phenomenon was that the mass looked like a secondary comet and had several tails of its own. From an inspection of the photograph it is clear that this object had its origin in the head of the comet, being simply a cloud instead of a stream of the repelled particles. Its system of tails was doubtless produced just as in the case of the parent comet, by the repellant action of the Sun.

The numerous tails frequently shown in the photographs of this comet (and in others since) were, it would seem, produced by different centers of emission in the nucleus of the comet—jets or streams of matter shot out from the different parts of the nucleus from different centers of activity.

According to the general theory of a comet's tail the action of the Sun upon the nucleus of the comet produces a repellant action in the nucleus on the sun-ward side and the particles thus expelled by the comet are met by the pressure of the Sun's light and driven back behind the comet to form the tail. This theory was sufficiently comprehensive to account for essentially all the visual phenomena of a comet's tail. But it does not satisfactorily account for the great number of thin diverging rays and thread-like streams shown by photography so often to be the main feature of the tail.

Indeed there are cases where a straight secondary tail or streamer makes a very large angle 45°—or more—with the main tail. It does not appear that the repulsive force of the Sun alone can account for this feature. And there are other peculiarities in the tails of comets shown by photography which rather suggest that a comet has more to do with the production of its own tail than has generally been conceded to it, further than simply supplying the material for the making of the tail.

Brooks' comet of 1893 presented phenomena unique in character and not susceptible of the explanation offered for the previous comet. Indeed the singular freaks of that comet's tail compel us to seek an explanation in some outside cause—inherent neither in the comet nor in the Sun. The tail which one day was in a normal condition, was on the next broken and disturbed as if it had

PLATE II

BROOK'S COMET

1893 OCT. 21 $0^h\ 35^m - 1^h\ 10^m$ G. M. T.

BROOK'S COMET

1893 OCT. 22 $0^h\ 37^m - 1^h\ 12^m$ G. M. T.

PLATE III

BROOK'S COMET

1893 Nov. 3d $0^h\ 0^m - 1^h\ 25^m$ G. M. T.

encountered some resisting medium in its flight through space. The disturbance seemed to come from the direction towards which the comet was moving. On the succeeding morning it was badly broken and hung in cloud-like masses, some of which were entirely torn off from the tail and appeared to be drifting away in space. On another occasion the tail was concave towards the direction of motion and had the appearance of beating against a current of resistence. It was disjointed in places, and near the end was abruptly bent at nearly a right angle as if at that point it had encountered a stronger current of resistence. If one examines these pictures there seems no escape from the conclusion that this comet's tail did actually encounter some resisting or disturbing medium about the 21st of October 1893 and for several days subsequent to that date, whether this was a swarm of meteors—such as we know exist in space near the Sun, or some sort of resisting matter of which we as yet know nothing is a subject for time to settle.

Photographs of Borrelly's comet on the night of July 24 showed a large section of the tail apparently completely broken off and displaced from the direction of the remaining portion of the tail, there was nothing in the appearance of this to suggest any outside disturbance. The section was straight and apparently uninjured. Other photographs made four hours earlier and three hours later showed that this section was receding from the comet and that the normal tail was growing in length. Determining the motion of the fragment from these photographs, it was shown that it must have separated from the head at 2:30 P. M., G. M. T. of July 24. Photographs of the comet on July 23 and July 25 showed nothing of this phenomenon.

The explanation of this feature appears to be a very simple one. It would seem that, for some cause, between two and three P. M. of July 24 there occurred a slight but sudden change in the direction of emission of matter from the comet. The first tail would then separate from the comet—as its supply of material would be cut off—and a new tail would begin in the new direction and grow to the normal length, while the section would drift out and dissipate into space. Thus would the phenomenon of July 24 be produced. The actual velocity of separation, determined from the photographs was 29 miles a second. As the comet was approaching the Sun at the rate of 22 miles a second, the real motion of the particles away from the Sun was 7 miles a second. This is a rather small velocity compared with some of those attributed to the particles composing a comet's tail.

This comet showed us that the tail actually moved out from the head as a luminous stream which remained visible for hours after its supply from the head had ceased. At the same time this section had a progressive motion laterally, which would partake of the original motion of the comet when the separation occurred. Let, therefore, this drifting stream encounter, say a dense swarm of meteors, or some other resistence and a disruption of its symmetry would occur—just as seems to have happened in the case of Brooks' comet of 1893.

This feature of Borrelly's comet seems to have been unusually well photographed both in this country and in Europe.

By a combination of measures of three photographs—the first at Nanterre, France by F. Quenisset, the second and third at the Yerkes Observatory by the writer and Mr. R. J. Wallace, respectively, the following values of the hourly motion of separation of the tail from the head was obtained.

Nanterre and first Yerkes Observatory plate 10′.1. Interval $4^h\ 35^m$
First and second " " plates 10 .7. " 2 59

The mean of these is 10′.4 for the hourly motion of separation.

I am convinced now that the slight difference between the above two values is due to the uncertainty of the measures. The small scales of the photographs and the ill-defined condition of the comet would not permit any closer agreement if the motion were uniform.

It appears therefore that there is no evidence of acceleration in the motion of separation. This is contrary to what would happen if the particles had been driven away from the comet by the repellant action of the Sun alone. For previous to its free existence the particle would be moving towards the Sun with a velocity of 22 miles a second—as a part of the comet. After it had become independent and subject to the repulsive action of the Sun, it would still approach until the repulsive force checked its speed, when for a moment it would become stationary and then begin to recede, at first slowly, and then with rapidly accelerating velocity. This would be its action if due alone to the repulsive force of the Sun—or the pressure of the Sun's light.

Assuming the correctness of the generally accepted theory of cometary tails, the want of acceleration in the motion of the fragment is puzzling, and would rather show that the Sun had little to do with its flight into space.

Some exception may be taken to the explanation I have offered for the cause of the phenomenon of July 24 in reference to the sudden change of the direction of emission of the particles from the

PLATE IV

SWIFT'S COMET

1892 APRIL $4^d - 5^d$ $23^h\ 25^m - 0^h\ 30^m$ G. M. T.

SWIFT'S COMET

1892 APRIL $7^d - 8^d$ $23^h\ 45^m - 0^h\ 35^m$ G. M. T.

head. It is only necessary however to examine the series of hpotographs of Swift's comet—or indeed of almost any other comet —to see that changes vaster than this rapidly take place in the form of the tail. One day it will be made up of a dozen thread-like strands, and the next of but one broad stream. Small divergent tails will form and rapidly die away and others spring forth in some other direction to take their place. I can see no objection to the supply of the main tail itself being suddenly stopped to break out afresh at some adjacent point producing a phenomenon like that of July 24.

The facts still remain however and there seems to be no other satisfactory explanation of them.

YERKES OBSERVATORY, November 1903.

THE WIDER FIELD FOR THIS MAGAZINE.

W. W. PAYNE.

This magazine has completed its eleventh volume, and the time has come for some important changes in its scope and the details of its general management.

Some years ago, when we advanced the idea of popularizing astronomy through the agency of a monthly magazine, some scholars of prominence said such a thing is impossible, others ridiculed the idea, and said it would belittle astronomy and so falsely set forth its great principles that the uninstructed would be misled, and the science would lose by means of such propagation as time went on. Still others took a middle ground, assuming that some work might be done in the way of popularizing astronomy by lessening the use of technical language which was then so common in most of the standard writings and in the formal treatises of the day; but, that part of the science which requires the higher mathematics for its proofs, its developments and its working theories, even these scholars held that it was very doubtful if this large and important part of the science could be popularized in the way we have suggested and maintain its integrity and preserve its unity.

We can now easily contrast the views of astronomers held a quarter of a century ago, which are briefly outlined above, with those more generally held now by workers in the various branches of modern astronomy. Then, the severe mathematical proof was the main thing which occupied the attention of the investigator, and too often his mathematics was such a cumbersome instru-

ment, or such a dull tool, that his work was slow, painstaking and inefficient. If one should ask for a translation of such work into a ready, clear and definite popular statement, it would not be a wonder if its author should hesitate to undertake such a task, or, refuse to do it because of the supposed or real impossibility of it. Now, our higher mathematics furnishes a very different system of logic from that in use a few years ago. Methods are abbreviated, proofs are more general and more easily acquired, and the needs of the older astronomy are nobly met by the present advanced state of pure mathematics. The scholars in its higher branches have done so well in modern times that astronomers are justly proud of them. They have little ground comparatively for complaint. They however need more help in some ways; for example, in the problem of three celestial bodies, so as to avoid the present tedious work of tabulating data for the predictions of the places of bodies moving in, or through, the solar system. There are some other things that might be mentioned which the astronomer would gladly receive from the hand of the mathematician to improve his method of work and to save him valuable time. But, the present state of the older branches of astronomy is such as to tend plainly to popular expression, for the benefit of hundreds of intelligent readers now, where formerly scarcely a single one could have been expected. Now, mathematical astronomers are writing stories for the magazines, in which the conclusions of science are employed, as the enticing data of the scientific imagination in clever plots that embrace the very end of the world in all the dread and scenic tragedy of its final destruction by fire. This is, indeed, an unexpected way of popularizing astronomy. We wonder that pictures of such vengeance should ever disturb the placidity of grave and venerable astronomers of the present day.

The new astronomy, so called, is even more effective in popularizing the modern phases of the science than the old, because its resources are so well adapted to that end. Its work is largely observational, both in physics and in astronomy, and its results, important and general, as they are, can be easily stated, especially concerning that part of the science which depends mainly on the revelations of the spectroscope and the photographic plate. The great results to astronomy that have already come through the use of these instruments have made an epoch in the history of science, although their work is yet almost entirely in its elementary stage of advancement. The severer problems which the new methods will be called upon to solve are surely

coming, and some of them are already here, and they are sorely trying the patience and skill of the best scholarship both in mathematics and physics. We have only to think of what the spectroscopist is doing with the problems of motion of the stars and nebulous masses in the far-off stellar depths, to see what he must consider in regard to physical conditions before he can make safe predictions of their speed and mutual influences upon one another in free and constrained motion.

On the other hand the astronomer is using photography in many ways for making records of important astronomical data for preservation and for critical measurement. One of the most interesting features of this work that has been going on during the last two years pertains to the new planet Eros. Astronomers, in all parts of the world, hnve taken photographs of this little planet as it was rapidly travelling among the stars, on as many clear nights as possible, that they might know very exactly what path it *appears* to traverse in the sky, so as to compare this apparent path with the real path which is already well known. The difference between the real path and the apparent one will help the astronomer to tell how far the planet Eros is from the Earth, and when he knows that he can tell how far the Earth is from the Sun, he hopes, more accurately than he now knows. But in order to gain this knowledge, he must measure the distances of the planet from the stars as it passed by them, very carefully and very accurately, to make the plates worth anything at all, for finding its distance or that of the Sun; for the latter is already quite correctly known, the error being probably not more than 150,000 miles. In order to make this error in our knowledge of the Sun's distance certainly smaller it will require the very best work that the astronomer can do in the use of physical measurements and in the methods of reduction that require the severe use of the higher mathematics. We notice, very recently, that there is some difference of opinion in the minds of eminent astronomers concerning the way that the measures of these Eros photographic plates should be reduced in order to obtain the most accurate results from them. This is another instance in which mathematics applied to new uses, in different ways, may involve uncertainties that will prove harmful in some degree, we can not yet tell to what extent.

From the citation of these examples of the present condition of astronomy, old and new, it seems as if it were easily possible, now, to enter on a wider and more comprehensive range than heretofore in the treatment of astronomical themes in a popular

magazine like our own; and this number is only the beginning of this new venture. Other changes will follow as the plan is more fully developed.

Only a little more needs to be said beyond that which was indicated in our last issue respecting the larger field now open to this publication, and that will concern an important new feature that ought to make the magazine more largely useful than any of its predecessors have been. We mean the feature of a regular review of current astronomy. This phase of our science is weak everywhere. A critical review of the various publications of practical astronomy as they appear would certainly meet a need very generally felt, but nowhere faithfully and intelligently provided. The number of regular publications in particular branches of astronomy and the greater number of scientific papers of every kind that come to our book table every month are legion. That which we see or know about must be only a small part of the useful matter in constant circulation. What is most needed in regard to this condition of things is some means of sifting this continual harvest of literature, retaining for suitable record the worthy part of it, with proper credit, and justly criticising the useless and the vicious to lessen as much as possible its harm and its repetition. To carry out such a plan as this needs the aid of many specialists. One or two scholars can not do it alone, however able or willing they may be to undertake such a large and varied task. On the other hand the many, able astronomers that are now to be found in the United States could do such a work very easily if there were some plan devised by which each one should do only a little of that which he knows how best to do, the results from so many sources might be brought together in an orderly way that would mean much to many. Some such plan as this is now under consideration and will be carried into effect in the near future.

As already said some of the details of our wider plan have been suggested, by conversation and by letter, to many well-known and able helpers during the last month, and, it is a pleasure to say that happy and most encouraging responses have come to us from every side. More in detail will be given next time.

JESUIT ASTRONOMY.

JOHN SCHREIBER, S. J.*

FOR POPULAR ASTRONOMY.

PART I. THE OLD SOCIETY, 1540-1773.

In the following pages I have attempted to jot down a few notes concerning the Jesuits of the 17th and 18th centuries and their relation to astronomy: I say notes, because more than that these lines cannot claim to be; as a long sickness has prevented and still† prevents me from making them more complete, orderly and uniform.

It is certainly a great tribute, redounding to the honor of the Jesuits no less than to the fairmindedness of Professor Förster, Director of the Berlin Observatory, when he says in the *Vierteljahresschrift of the Astronomische Gesellschaft*: "Amongst the members of the Society of Jesus in the past and in the present we find so many excellent astronomers, and in general so many investigators of purest scientific devotion, that it is of important interest to their colleagues in science to notice them etc.."‡

This portrayal by no means claims perfection or completeness for them, but it will probably show that the relation of the old Jesuits to astronomy was very heartfelt, very intimate and well cultivated, and that astronomy was treated in an anything but step-motherly way.

I speak exclusively of the old Jesuits, and understand thereby those who were members of the Society before its suppression. The Society of Jesus was founded in 1540, and was dissolved through the intrigues of the Bourbon courts in 1773. It is self-evident that beginnings were very modest, and the still not-numerous Jesuits so much occupied by their chief work, the application of their zeal to the salvation of souls directly, that scientific labors in the direction mentioned were not to be thought of. Hence the interval in question is narrowed down at best from 1550 until 1800, that is, to about 20 years beyond the Suppression, since many ex-Jesuits, who had received their education in the Society, lived and labored until about that time. Although

* "Die Jesuiten des 17. und 18. Jahrhunderts und ihr Verhältnis zur Astronomie" by Johann Schreiber, S. J., Assistant Astronomer at the Haynald Observatory, Kalocsa, Hungary. *Natur* und *Offenbarung*, Vol. 49, 1903.—Translated by William F. Rigge, S. J., Creighton University Observatory, Omaha, Neb.

† Father Schreiber, the author, died March 10, 1903.

‡ *Vierteljahresschrift der A. G.* 1890, page 60.

these studies were not their exclusive nor even their principal aim, they have nevertheless during these two and a half centuries been able to do valuable work.

Poggendorff's biographical dictionary of the exact sciences contains in its first two volumes the names of 8,847 savants from remote antiquity until 1863. Amongst these names which embrace many centuries, we find that a little more than 10 per cent are Catholic clergymen, a number by no means to be despised, when one reflects that the rest for the most part, as the notes about them prove, belonged to a profession which obliged them to do something in the exact sciences, such as engineers, professors of physics and mathematics, chemists, hydrographers, nautical men, and the like. And amongst the Catholic clergymen, who have done literary work in the domain of the exact sciences, the Jesuits again number over 45 per cent. So that among the great number of men of all times who have done literary work in the exact sciences, the Jesuits during the short space of 2½ centuries, figure up a very respectable sum, nearly 5 per cent.

It appears from De Backer's Bibliothèque des Ecrivains de la Comp. de Jésus, 1876, and with the aid of its annexed Table méthodique, that 217 authors have done literary work in astronomy specifically. This does not mean that all these productions were very excellent, but at all events it follows necessarily that in the Society of Jesus astronomy had by no means gone to sleep, but had developed a busy life, and as far as matters were destined to go, had blossomed to an ever-increasing extent. We may, of course, lay some stress upon the circumstance that in former times, when, as far as words are concerned, much less learning was required of individuals than today in our age of examinations without number and without end, the knowledge of the principles of astronomy was spread farther and more generally than now;* because almost all of those of the Society of Jesus who were engaged in astronomy, even those who were in any way prominent, took up astronomy so to say, out of private zeal, for they were primarily bound to attend to other functions, for instance, as professors of mathematics, philosophy, theology, or frequently as rectors of important colleges.

Astrology.

At the time that the members of the Society of Jesus began their astronomical activity, the status of astronomy was not well defined. Astronomus, astrologus and mathematicus were

* Dr. *Karl Kostersitz.* Über Bergobservatorien. Vienna, 1901.

very ambiguous terms. They might mean as well astronomer in our sense, as astrologer in our sense, that is, a savant, or a cheat as well, who has recourse to divination; or again in many cases both, a savant, who, while not exactly intending to deceive, was not able to emancipate himself completely from the views of his age, especially as divination was held in higher repute than true astronomy, and astronomers were in danger of starving to death, if they did not in addition dabble in astrology. This was the condition of affairs at the beginning of the 17th century. The good and great Kepler himself could not entirely escape this danger; he admits it himself: "This Astrology may be indeed a foolish little daughter: but, good God! where would her mother, the highly intelligent Astronomy remain, if she did not have this silly daughter. * * * And the Mathematicorum salaria are so meager that the mother would surely suffer hunger, if the daughter did not earn anything."

At all events Kepler seemed really to believe in astrology to some extent and not to indulge in pure deceit. Thus he once wrote a letter to Fathers N. Serrarius and J. Ziegler in Mayence, October 18, 1606; he sent them a work he intended to publish, and asked them for their opinion (for the Protestant Kepler was upon the best terms with the Jesuits) and said they should speak out their minds freely, he was not so sensitive * * *, at most they might pick a slight quarrel with him on account of astrology, but he believed that he was yet within the limits of the permissible.

In this weakness he had yet many models and colleagues of high-sounding names, such as Nostradamus, Regiomontanus, Stöfler, Melanchthon, etc.

With this astrology, the separation and removal of which from astronomy, was assuredly itself a meritorious work, the Jesuits were by no means on good terms. Already in 1591 Father Benedict Perrerius made a vigorous attack upon it. He wrote a work on the different kinds of superstitions, and very particularly "de divinatione astrologica." It went through five editions. In like manner Fr. Alexander de Angelis "In Astrologos conjectores" libri 5. Romæ, 1604. In the year 1676 the 7th edition entered upon the field. Fathers Roberti, Renaud, Pinamonti, Noceti, did similar work. Fr. Nicolas Caussin in 1649 published in the press a letter to a "personne illustre sur le curiosité des Horoscopes." The horoscope, that is, divining the character of a person from the positions of the stars at his birth, in other words, predicting —or mendaciously fabricating—his future fortunes, was,—I am

using the words of the Zürich Professor Wolf—"from the beginning a pure fraud and one most known to deceive," but one altogether indispensible to "personnes illustres." I draw attention only to Rudolph II, Wallenstein, Gustavus Adolphus, Catherine de Medici—; the 16th and 17th centuries could not exist without the noble art, astrology, so that Father Riccioli, in his famous work, the Almagest (I, 21) could say as late as the year 1651, that such people would always be found, and with Tacitus call them genus hominum "quod semper in Urbe vetabitur et semper retinebitur," only, he says, it ought to read in Orbe.* The fight against this superstition was certainly a deserving work.

Observatories.

The predilection for astronomy in the Society of Jesus stands out most clearly in the erection of observatories. I say, in the Society of Jesus—and truly as such; for this is not the affair of one man, let alone that of individual members of an Order not one of whom can dispose of a cent. Now the Society of Jesus has not only itself during its comparatively short existence erected a very considerable number of observatories, but was also in a condition to accept some of those that had been erected at government expense and to man them with appropriate talent.

Of course, the first observatories in which the Jesuits did work, were not observatories in the modern sense; this is true in general in regard to all the observatories of that time; they were only modest beginnings. There were proper sites, some necessary instruments, that were probably completed in course of time, some observers, and industry and zeal for science.

The first greater observatory which was fitted out by the Jesuits, was a government one,—built at the expense of the Celestial Kingdom,—in Peking, where astronomy had for ages past been held in high esteem, of course, more on the score of utility, in order to seek advice in all possible transactions, even the most intricate affairs of state, advice which the stars gave gratis very willingly, through speaking tubes, however, that did not always furnish their interpretation according to eternal laws. Nevertheless, we are indebted to the citizens of the Celestial Kingdom for

* v. Littrow says in his "Wunder des Himmels" (1886, p. 604), where he treats of these absurd things: "Whoever takes pleasure in these fairy tales, can find them in the works of the well-known Jesuit Riccioli (Almagestum novum)." Yes, certainly, but Riccioli communicates them "exaliorum magis quam Nostra opinione," and concludes thus: "Jam enim me taedet, in incerte Astrologorum pulvere lusum prolixiorem ludere," that is, it disgusts me to continue such low play. May this serve to complete, if not to correct, v. Littrow.

many very ancient, perhaps the oldest, observations. When the Jesuits were directing their steps towards China, astronomical knowledge was, of course, in a sorry plight, and it was time for a thorough reform. The intelligent emperor Cham-Hi then transferred the superintendency of the heavens to the Jesuits, their first task being to cut off with technical exactitude the cue of the Chinese astronomers which hung down heavily behind, and to offer them European fashions instead. It was a piquant coincidence, that contemporaneously with the erection of the Paris Observatory, Father Verbiest S. J. in Peking, in the Kingdom of the Centre, was equipping a sister institution in up-to-date European scientific style (1668). This observatory is the fourth of its kind of government institutions, as only the observatories of Leyden (1632), Copenhagen (1637) and Paris (1667) antedate the time of its erection. Fr. Verbiest was therefore the first director of the observatory, styled in Chinese the President of the Mathematical Tribunal, and from that time until the death of Fr. Hallerstein in 1774 a Jesuit always filled this position.

In order then to indicate briefly the activity of the Jesuits at this observatory, let me cite the passage from De la Lande's *Astronomia* (p. XXXIX) referring to it: "This observatory was not at all unprofitable; a great many good observations were made there, of which Fr. Gouye, in 1688 and 1692, published a part; and again Fr. Souciet a part in 1732; many of them also are to be found in the manuscripts of Mons. de l'Job. The Fathers Fontaney, Ricci, Gautil, Benoît, Jacque, Kegler, and Slaviczeck and many other Jesuits have distinguished themselves there." And in the *Memorias de Mathematica et Physica da Academia R. das sciencias de Lisboa*, Tom. II 1799, "Eclipses and occultations observed in Peking from 1753 until 1795 by Andreas Rodriguez." In like manner Hell in Vienna published in 1768 "Observat. astr. ab Anno 1717 ad annum 1752 Pekini Sinarum factæ etc."

Government Observatories.

Among the government observatories conducted by the Jesuits the following must also be mentioned:

Vienna. An observatory was erected there in 1745 as an annex to the university, but completed only in 1756. This was the beginning of the present university observatory. For it was reconstructed in 1820-1826 and in 1879 transferred to the Türkenschanze. A small observatory had indeed already existed in the Collegium Academicum since 1735 under the direction of Fr. Franz, but while a public one, it did not have the title of a uni-

versity observatory. The directors were Father Hell, 1745, and Father Triesnecker, 1792.

Wilna. The university observatory was founded in 1753. Fr. Poczobut restored it and completed the instrumental equipment, was appointed its director, and remained even after the Suppression in the same position and with the same staff of observers, as the most of them were ex-Jesuits.

Schwetzingen 1764 and *Maunheim* 1772. Built by the Elector Theodore of Palatine; Fathers Christian Mayer and John Metzger especially worked there.

Private Observatories.

Outside of these government institutions the Jesuits possessed also many observatories erected with their own funds. I mention only the most prominent.

Marseilles. In 1702 the Jesuit college of S. Croix erected a small observatory, at which amongst others Fr. Lavel and later Fr. Pézénas observed. Fr. Pezenas equipped it richly with instruments, mostly at his own cost, and obtained a pension from the queen in order to support two Jesuits as assistants. He himself was director until the Suppression of the Society. This scientific institution was taken in charge by the Administration of Marine in 1749, but the Jesuits remained there.

Lisbon (1722). Founded in the college of St. Anthony, it was taken in charge by the government in the year 1728, and transferred to the royal palace. The first director was Fr. Carbone S. J.

Prague. The modest observatory existing already was completed by Fr. Jos. Stepling, and equipped by him with new instruments at the expense of the Bohemian Province of the Society of Jesus; in 1761 Fr. Stepling also devoted to the observatory the inheritance of 4,000 florins coming to him after his mother's death. He increased the library of the Clementinum (so the enormous College of Prague was called) by about 600 of the best mathematical works, so much so that a section was called the "Mathematical Library." He directed this observatory from 1751 until his death in 1778. After the Suppression it became and is still the government university observatory.

Vienna. At first the beginning of an observatory existed under the title of "Mathematical Cabinet," in the erection of which the greatest credit is due to Fr. Ernest Vols. He died in 1720. The academic college possessed some instruments since 1735, which were used by Fr. Franz. This private observatory still continued

after the erection of the university observatory in 1745. Fathers Liesganig, Pilgram and others were especially prominent at this observatory.

Milan. Fr. Pascal Bovio and Fr. Dom. Guerra, professors of philosophy in the college of Brera, erected in 1760 an achromatic telescope of 40 feet focus, and also an armillary sphere and a pendulum-clock, and thus founded an institution which must be considered as the origin of the present observatory (Obs. di Milano). The need of finer measuring instruments was soon seen, and the rector of the college, Fr. Pallavicini, a man very enthusiastic for science and himself very learned, provided some instruments. In 1762 Fr. Lagrange, already renowned through his labors in Marseilles, became director. Then Fr. Boscovich, called by the senate of Milan to be professor of mathematics at the Pavia university, came to Milan, managed the erection of a more suitable observatory, and acted for a while as director. After him came Fr. Lagrange again. The Jesuits had spent 60,000 livres on the observatory.

Florence. Fr. Leonhard Ximenes, who had won great renown for himself especially in hydraulics, was commissioned by the emperor to settle the boundary difficulties between Toscana and Lucca. No question in hydraulics was treated in Italy without being submitted to him. He applied the means coming to him from his father's fortune and his own various official positions, to adorn Florence with a scientific institution. He founded the observatory of S. Giovannino, renowned for its great mural quadrant and the famous gnomon of Toscanelli, which Ximenes restored. He added an excellent library and a large number of instruments. After a pious and laborious life he died at the age of 70 years in 1786. In his will he founded two professors' chairs, one for astronomy, and the other for hydraulics, which were to be filled by two Piarist religious priests, to whom he also deeded his library and his cabinet.

Rome. "Observatorio di Collegio Romano,"—which however no longer belongs to the Roman College, but along with all its valuable instruments was acquired by the government in 1870 in a very profitable and cheap way, that is, was declared to be government property, an act which, of course, settled the question of justice. The beginnings of this observatory date far back. The buildings of the Roman College which were erected in succession at various times, have for a long time back given shelter to astronomical instruments. In the old Roman College Fr. Scheiner gathered the material for his chief work Rosa Ursina, in which he

exhaustively treats of the science of the Sun as known in his time, and used there the first telescope mounted equatorially. The same building saw the labors of Fr. Clavius, who observed with a zenith sector as early as 1572, of Fathers Grienberger, Gottigales, Asclepi, Borgondi, Boscovich, and many others. A more suitable place was being projected for the observatory, but the Suppression of the Society put an end to these plans. In 1824 the observatory was again given over to the Society, and under de Vico, Sestini and Secchi it became a modern observatory equipped with the best instruments, at the expense partly of the Society, and partly of the private means of Piux IX. But this date already transcends the time limits marked out in this paper.

Parma. In 1757 Fr. Belgrade allowed one of the two towers of the college in Parma to be changed into an astronomical observatory.

Pout-à-Mousson was provided with a good observatory and equipped with very good instruments. Here amongst others Fr. Collas, who went to India in 1767, and Fr. Barlet, observed a partial eclipse of the Sun, which the Paris astronomers had neither predicted nor announced. The details of this observation were given in all the papers of that time.

Graz. The new building of the astronomical observatory was begun in 1745: the college contributing 7,000 and the Provincial of the Order 2,000 florins. The Jesuits did very much for this observatory, as for instance, establishing a special fund for its maintenance, which amounted already to 4,300 florins in 1773. Here Fr. Liesganig determined the meridian of Graz, Fr. Tirnberger discovered the comet in 1769, and Frs. Bode and Biwald worked. Things went on in this way until the Suppression of the Society, and then?— Then it was judged proper to do away with the chair of astronomy, to lock the observatory, to give over the capital to the students' fund, and at the very end in 1787 to tear down the mathematical tower—under the plea of "unnecessary."

Lemberg. Von Zach, who was by no means a special friend of the Jesuits, writes in regard to the Lemberg Observatory:* "It is a pity that at a time, when the science of the stars is obtaining new protectors and warm promoters in all countries, already existing institutions, which might advance this science, should go to ruin or be neglected. While the Order of Jesuits was still in existence, the Lemberg College had in connection an observatory which was pretty well provided with various astronomical in-

* Monatl. Korrespondenz von v. Zach, Nov. 1801, p. 547.

struments. * * * Later on this astronomical tower was entirely demolished, so that no trace of it is left any more. * * * There was no dearth of pendulum clocks, and amongst them a fine English one by Graham. * * * These clocks are scattered amongst the various professors and serve as ornaments to their rooms."

Tyrnan. The observatory in Tyrnan in Hungary was erected in the years 1753-1755 in the great college there with which the university (now in Budapest) was connected. The observatory was 110 feet high, the observing tower attached to the building 18 feet high, 56 feet long on the longer side and 40 feet wide on the shorter, and provided with an underground space 12 feet deep, which was intended especially for the comparisons of the baroscope and thermoscope above and below. It was built under the direction of Fr. Francis Weiss, who was appointed the director, his assistants being Fr. John Sajnovits and Fr. Francis Taucher. At the time of the Suppression of the Society the observatory had a small fund of 2,290 florins; at the Suppression things were managed with greater forbearance than they were for instance in Graz and Lemberg, as the government desired the observatory to continue, and even promised to defray out of the university treasury what was necessary over and above the 120 florins of the interest of the above capital. Of course, the confiscated property of the Jesuits was more than sufficient for this purpose. Fr. Weiss remained the director and professor of astronomy at the university, the former assistant at the observatory remained in his position with a salary of 600 florins. Fr. Weiss' (1717-1785) astronomical observations and treatises had spread his name in astronomical circles even in foreign countries, according to the assurances of the royal commissaries in 1774. He was also invited by the Elector to the Mannheim Observatory, but he declined.

This would finish the enumeration of the most prominent observatories; for there were others also of lesser importance concerning which I could not get more particulars, as Breslau, Olmütz, Ingolstadt, Dillingen, Toulon and others.

Astronomical Inventions.

Let this suffice for the observatories. Now only a few words about three contrivances which figure very prominently even at present in all observatories, and which owe their existence to three Jesuits. The first is the vernier. Probably not a single astronomical angle-measuring instrument, not a theodolite, not a

universal instrument, not an equatorial, is to be found unprovided with verniers. It consists essentially of two scales, moving upon one another, and so arranged that when one of them, for instance, is divided into degrees, the other has 10 divisions corresponding to 9 degrees of the first, and in this way reads to tenths of a degree. The inventor is Fr. Christopher Clavius. (Famous mathematician, died 1612 in Rome).

Brensing writes as follows in his article "Nonius or Vernier" in the *Astronomische Nachrichten:** "Clavius has been forgotten or neglected in an unintelligible way; I was surprised when I came upon the following passages in his works (Christophori Clavii Bambergensis opera, Moguntio 1611):" —he cites in full—; and then continues: "These passages give the clearest proof that we are indebted to no other than Clavius for the theory of vernier subdivision, as well for linear as for circular measurements. They have been overlooked." Professor Wolf of Zurich thinks that this contrivance should be called neither Nonius, nor Vernier, (the assigned inventors) but rather Clavius.

The second contrivance to be found in all observatories is the equatorial mounting of the telescopes, which, when they are of a certain size, are then simply called equatorials. The arrangement consists in turning the telescope about an axis which is parallel to that of the Earth, so that when the telescope is perpendicular to this axis it moves in the plane of the equator, when it is turned up or down, it always moves in parallel circles, thus enabling one always to keep a star in the field of view without difficulty, when once the tube has been set upon it. The invention of this important contrivance is derived from the Tyrolese Father Christopher Grienberger (died 1636 in Rome). Fr. Christopher Scheiner says in his chief work, Rosa Ursina, p. 352, that Fr. Grienberger endeavored to invent this mounting for the special purpose of making daylight observation of stars possible. The first observation with this kind of mounting of which we can find a record, was made on March 4, 1627, by Fr. Scheiner, who used it for his solar observations, "because, he says, although Fr. Grienberger has lately constructed this machine for other purposes, it is specially suited for my work." He adds also that he describes the machine "because, as it seems, the inventor of this instrument will not do it himself." Thanks therefore to Fr. Scheiner that it was not forgotten on account of the modesty of the inventor, or connected with another name, as happened to the vernier of Fr. Clavius

* *Astr. Nach.* Vol. 96, p. 131.

which was brought to light and ascribed to its inventor only after 270 years.

But Fr. Scheiner also here deserves a mention. I will not speak of his inventing the pantograph, so generally used today, and that too in both of its styles, because it does not strictly belong to astronomy. It has been proved that in order the better to observe sun-spots he constructed the first *astronomical* telescope, that is, one consisting of convex glasses exclusively in opposition to the only one hitherto used, called the Dutch telescope, which had both convex and concave glasses (1613), the advantages of his being such that it later on almost entirely superceded the Dutch telescope.

The idea of the reflecting telescope also comes from a Jesuit. The thought of replacing the objective lens by a mirror was announced as early as 1606 by Fr. Nicolas Zucchi (Parma 1586—Rome 1670), and carried out at least in so far that he took the image made by a concave mirror and examined it with a concave lens.

Another important invention, which I would put down as the third, and which is continually being used even at present, especially in observing comets or other such objects which do not admit of artificial illumination in the field of view of the micrometer of the telescope, was the happy idea of Fr. Roger Joseph Boscovich (Ragusa 1711—Milan 1787) of using the circular field formed by the last diaphragm in the telescope as a micrometer—called a ring micrometer. The ring micrometer is often ascribed to Huygens, but, as Wolf* shows, falsely so. The field of view of the telescope was, of course, being used for measuring the diameters of the planets, a method which appears already in Fr. Scheiner; Huygens added a contrivance to this to facilitate this measurement. But this was no ring micrometer in the present sense, by means of which the difference of position of two stars is computed from the times of their ingress and egress. It was an occasion of the comet of 1739 that Boscovich showed it was exactly in comparing such an object, which scarcely admitted of a field illumination, with a neighboring star, that the observation of the times of entering and leaving the field of view of the telescope furnished the data for computing the difference of right ascension and declination, and he developed the appropriate theory. This ring micrometer was later on fitted up by Frauenhofer in excellent shape, so much so that now it occupies a place among

* Wolf, *Handbuch*, Vol. II, p. 128.

the instruments of precision of every observatory, and in the observation of comets it is used almost exclusively.

(TO BE CONTINUED.)

THE CREIGHTON OBSERVATORY, OMAHA, Neb.

THE RELATION OF THE MASS OF THE UNIVERSE TO STELLAR DYNAMICS.

LUIGI D' AURIA.

FOR POPULAR ASTRONOMY.

Supposing the stars to be scattered without any great and well-marked deviation from uniformity and to constitute a system approaching the form of a sphere of some finite radius ρ, the acceleration or retardation upon any one of the stars caused by the mass M of the *ensemble* would not differ much from that produced upon a material point occupying the place of the star by a sphere of gravitational medium of radius ρ and uniform density

$$\sigma = \frac{M}{\frac{4}{3}\pi\rho^3} \qquad (1)$$

In other words, on this supposition, we could study the dynamics of the stars by considering these bodies as material points moving in a hypothetic uniform medium having for density the value of σ given above.

In a paper entitled "Stellar Dynamics," read May 13, 1897, before the American Philosophical Society of Philadelphia, published in the *Journal of the Franklin Institute*, Oct., 1897, I showed that the acceleration of a body contained within a sphere of gravitational medium of uniform density σ, at any distance x from the center of this sphere, would be

$$\phi = g\frac{\sigma x}{RD} \qquad (2)$$

in which R and D are the mean radius and the mean density of the Earth, and g is the mean gravitative acceleration at the Earth's surface. In this paper the effect of the mass of the stars was neglected, that is, the stars were considered simply as material points attracted by a sphere of gravitational medium of uniform density σ extending to the boundary of the stellar universe, and it was shown that, if devoid of angular motion, a star under these conditions would oscillate in a straight line passing through the center of this sphere with velocity

$$u = \sqrt{\frac{g\sigma}{RD}(a^2 - x^2)} \qquad (3)$$

in which a is the initial distance of the body from the center of the sphere, and x its distance at the instant of time considered.

If the body had been subjected to a tangential impulse, it was shown that it would revolve in an elliptical orbit around the center with velocity

$$u = \sqrt{\frac{g\sigma}{RD}(a^2 + b^2 - z^2)} \qquad (4)$$

in which z is the distance of the body from the center, and a and b are the semi-diameters of the ellipse. When the body revolves in a circular orbit of given radius a, we have to put $z = b = a$, and we get

$$u = a\sqrt{\frac{g\sigma}{RD}} \qquad (5)$$

that is, the same value which is given by (3) when $x = 0$, showing that the velocity of a star moving in a circular orbit is the same as that which the star would acquire in falling radially to the center of the orbit.

The period of revolution was found to be the same for any orbit irrespective of its dimensions, which period is expressed by

$$T = 2\pi\sqrt{\frac{RD}{g\sigma}} \qquad (6)$$

The amount of kinetic energy of translation of all the stars at any instant of time, supposed to be moving in various elliptical orbits, may be represented by

$$W = \frac{1}{2} v_0^2 M,$$

in which v_0 is the mean speed of stellar motion. As the mean stellar distance is $\frac{3}{4}\rho$, we may represent the maximum possible amount of kinetic energy of the stars by the product of $\frac{1}{2}M$ by the square of the velocity acquired by a star falling from this distance to the center of the universe, which product is

$$W_1 = \frac{1}{2} M \left(\frac{3}{4}\rho\right)^2 \frac{g\sigma}{RD}$$

Now if the stars were all moving in circular orbits we would have $W = W_1$, because then all the energy of the stellar universe

would be kinetic. If the stars were all moving in straight lines passing through the center of the universe, the energy would be half kinetic and half potential, and we would have $W = \frac{1}{2} W_1$. Averaging between these two extreme cases, we can put $W = \frac{3}{4} W_1$, or

$$v_0^2 = \left(\frac{3}{4}\right)^3 \rho^2 \cdot \frac{g\sigma}{RD} \qquad (7)$$

from which we get

$$\sigma = \left(\frac{4}{3}\right)^3 \frac{v_0^2}{\rho^2} \frac{RD}{g} \qquad (8)$$

Comparing with (1) and solving for M, we find

$$M = \left(\frac{4}{3}\right)^3 \frac{v_0^2 \rho}{g} \cdot \frac{4}{3} \pi RD = \left(\frac{4}{3}\right)^3 \frac{v_0^2 \rho}{gR^2} \cdot \frac{4}{3} \pi R^3 D,$$

and observing that $\frac{4}{3} \pi R^3 D$ = mass of the Earth = E, we can write

$$M = \left(\frac{4}{3}\right)^3 \frac{v_0^2}{gR} \left(\frac{\rho}{R}\right) E \qquad (9)$$

This formula, though not absolutely exact, is perhaps as close as the problem in question will ever allow us to go in the determination of the mass of the universe when the radius ρ and the mean speed of stellar motion v_0 are given.

The mean speed of stellar motion, according to the researches of Kapteyn, is $v_0 = 102{,}000$ ft. per second, and with this value, and the numerical value of gR in feet, we get

$$M = 36.7 \left(\frac{\rho}{R}\right) E \qquad (10)$$

Assuming for ρ the distance corresponding to the parallax of $0''.001$, or $\rho = 4.8 \times 10^{12} R$, we get

$$M = 1.76 \times 10^{14} E \qquad (11)$$

and, in terms of the Sun's mass S, we would get $M = 530{,}000{,}000\, S$.

Putting the above value of ρ and the value (11) of M in (1), we get $\sigma = 1.58 \times 10^{-24} D$, and with this value of σ the period of revolution of any star is found to be $T = 4 \times 10^{15}$ seconds, or about one hundred and five million years. Thus a star starting from rest from any point within the universal sphere would reach

the center of the universe after a time $\frac{1}{4}T$, or about twenty-six million years. A body placed originally at rest upon the boundary of the universal sphere would at the end of this time acquire a velocity of about 30 miles per second, which would be the maximum velocity of a star moving within this sphere.

As there are some stars possessed with speed much higher than this, and in the case of 1830 Groombridge, as high as six or seven times the above maximum, we must admit that either these stars have entered our universe with velocities of their own, or that there is a gravitational medium extending far beyond the sphere of the stellar universe, since a body, even if attracted to the boundary of this sphere from an infinite distance, could not attain a velocity higher than $1.4 \times 30 = 42$ miles per second. Now, if we adopt Newcomb's star density derived from stellar statistics, there would be in the sphere of radius ρ about 125,000,000 luminous stars, and, if we assume an equal number of dark stars, we would have in all 250,000,000 stars. Thus if the average mass of a star were equal to the Sun's mass, the density of the medium in question, if uniform, could not be greater than $\sigma_0 = \frac{1}{2}\sigma$, or say, $\sigma_0 = 8 \times 10^{-25} D$, which, in terms of the density d of atmospheric air, would be

$$\sigma_0 = 3.4 \times 10^{-21} d \qquad (12)$$

With this density the medium would have to extend to at least nine times the assumed radius of the stellar universe in order to hold 1830 Groombridge within its boundary and account for the great velocity of this famous star.

As it seems very unlikely that the average mass of a star could be less than the Sun's mass, we must consider the above value of σ_0 as the superior limit of density which a universal gravitational medium of uniform density could have if it actually existed. This limit of density is about 165 times smaller than the major limit of density assigned by Maxwell to the ether. Hence, Maxwell's major limit of density would be inadmissible if the ether were gravitational.

The common period of revolution for all the stars found above shows that, on an average, it would take a century for a star to describe an arc of 1″.2, and this is in accord with the fact that the proper motions of the stars since they were first observed show no appreciable curvature. This fact allows us to consider the projection of the proper motion of any star as that of the direction of the tangent to any number of plane curves of large

dimensions passing through the point occupied by the star, and therefore, however bewildering the projections of the proper motions of the stars may appear to be, we can always imagine them to be the projections of proper motions performed in various elliptical orbits having a common center. Hence, the fact that the position of this common center cannot be divined from the general arrangement of these projections, does not, as some astronomers have thought, conclusively disprove the idea that the stars are moving in orbits and constitute a system.

Concerning the position of the center of the universe, the quasi-symmetrical arrangement of the stars with respect to the plane of the Milky Way makes it very probable that this center is located in this plane. Now if we accept Kapteyn's estimate of the Sun's motion, about ten miles per second, we might account for this velocity by supposing the Sun to be moving in a circular orbit of radius $\frac{1}{3}\rho$, the corresponding parallax of which is 0″.003. But, so far as we can judge from the enumeration of the stars in all directions, and from the aspect of the Milky Way, our system is near the center of the stellar universe. We must conclude, therefore, that our Sun is moving in an elliptic orbit of large eccentricity, and is now near the minor semi-diameter, whose length is a small fraction of $\frac{1}{3}\rho$, which represents the length of the major semi-diameter of the orbit. Thus if the ratio between these semi-diameters were ten, the distance of the Sun from the center of the universe would be about $\frac{1}{30}\rho$, the corresponding parallax of which is 0″.03, but, for all we know, the Sun may be moving practically in a straight line and be passing through the center of the universe. All we can say from the results of our calculations is that the Sun's excursions in space are performed within a sphere the parallax at the surface of which is about 0″.003, in which sphere, according to Newcomb's star density, there would be found over six million lucid stars.

ASTRONOMY IN THE HIGH SCHOOL. II.

MARY E. BYRD.

FOR POPULAR ASTRONOMY.

THE CONSTELLATIONS.

The practical study of elementary astronomy begins naturally with the constellations. Whether our girls and boys have only

one short term with the subject, whether they go on with several years' study, or whether they are to be the astronomical teachers and astronomers of the future, let us begin by introducing them first to the pleasure of the stars. The world beyond the horizon line should be opened up to them, the world that is still new in spite of centuries of exploration. There should be unstinted enjoyment for them in the royal progress of celestial bodies, in the rising of the Pleiades and the Hyades and in the stately march of all the goodly host that Orion leads. They will not know less that they enjoy more.

Viewed also from the coldest academic standpoint, the study of the constellations comes first. It is necessary for practical work of any kind that our students know how to see when they look up at the heavens. To recognize different degrees of brightness, to determine angular direction, to estimate the relative length of star-lines, to pass by careful steps from a known to an unknown object, these things are fundamental, and yet they are best and most quickly mastered not by direct effort, but by picking out and drawing the constellations. Nor is this training of eye and hand by any means the only advantage gained. Familiarity with the star groupings themselves is of vital interest to naked-eye observers. For then in a very real sense the stars are fixed. They constitute the practically unchanging background upon which are displayed all shifting celestial phenomena.

It was by means of the fixed star-pattern that ancient peoples gathered a surprising fund of knowledge about the solar system. Our students of today should follow in their foot steps at least, for a little way. With the stars as reference points, they are to define the monthly course of the Moon, trace out long or short arcs of the paths in which the planets circle around the Sun, determine the direction of a bright comet's progress, and the length of its visible path, follow the flight of a meteor, and bound the zodiacal light. Without some acquaintance with the stars they cannot so much as know whether or not they are looking at a planet. Again and again at the coming of winter, otherwise intelligent people take Sirius for a planet.

Doubtless there are a score of good ways to teach the constellations. There are certainly a few poor ones. The different kinds of planispheres, illuminated star pictures and other like devices are, in the judgment of the writer, worse than useless. Even the celestial globe confuses rather than helps the average beginner. Any one who has studied geography and used a common atlas should begin at once with star maps which have the usual refer-

ence circles, with hours and degrees marked for right ascension and declination. It is not amiss to give a part of the first class-exercise to these maps, calling attention to points of likeness between them and geographical maps, noting how striking configurations are outlined and constellations bounded, and picking out the particular constellations to be identified on the first clear evening.

Since, with few exceptions, it puzzles beginners to recognize in the sky what is depicted on the map, some pains must be taken in giving explanations. The following is one of the common forms employed:

IDENTIFICATION OF THE BRIGHT STARS IN AQUILA.

1. Facing the arch of the Milky Way to the southwest and looking up a little more than half way to the zenith, you see right in the Milky Way a row of three bright stars, nearly equidistant, the brightest being in the middle. That one is α Aquilæ, called also Altair. The upper one of the three is γ and the lower β.

2. Prolong the star-line $\gamma\beta$ southward once and two-thirds its length and you find the fairly bright star θ.

3. From θ pass northward again to the Milky Way, and look to the right of α for the star δ, about as bright as θ, which with θ and α forms a fair isosceles triangle, θ being at the apex.

4. Through δ extend a line upward equal in length to $\gamma\theta$ and parallel to it. Near its extremity ζ is found.

5. Now if these stars have been correctly identified, $\gamma\theta\delta$ and ζ mark out quite a symmetrical parallelogram.

Time is saved in the end by going slowly at first, and patiently repeating directions. Even if it takes two or three evenings, it is well to wait till the class is familiar with ten or more constellations before requiring drawings. Any method or no method of mapping is practically satisfactory if the reproduction on paper fairly represents the configuration in the heavens. There are some advantages, perhaps, in using the card-patterns and construction lines suggested by the writer in a former article.* A card-pattern is simply a stiff piece of card board cut to fit the page of the observing book with two dots on one side for the stars that fix the reference line for the given constellation. Construction lines are best explained by a concrete example like the following:

CONSTRUCTION LINES FOR CASSIOPEIA.

$\alpha\beta$ = Reference line.

The stars $\alpha\beta\gamma\delta\varepsilon\iota\kappa$ must be included.

* POPULAR ASTRONOMY, March, 1902.

Estimate $<\beta\alpha\gamma$.
Compare $\alpha\gamma$ with $\alpha\beta$. Put in γ.
Estimate $<\alpha\beta\kappa$.
" $<\gamma\kappa\beta$. Put in κ.
Prolong $\beta\gamma$ and estimate $\delta\gamma$ in terms of $\gamma\beta$. Put in δ.
Prolong $\alpha\gamma$ and place ϵ and ι with reference to a line parallel to $\alpha\gamma$, drawn through δ.

Write out.

Estimate of $<\beta\alpha\gamma$.
" " $<\gamma\kappa\beta$.
" $\delta\gamma$ in terms of $\gamma\beta$.
" $\iota\delta$ in $\delta\beta$.

Working from such directions as these, beginners are likely to escape the worry and delay of futile efforts in getting started, and to realize from the first that emphasis is placed on accuracy in estimating lines and angles rather than on pictorial effect. For the laboratory instructor who must criticise perhaps fifteen or twenty maps in an hour, it is certainly no small gain to have all those of one constellation drawn on the same scale, similarly placed on the page, and based on the same measurements.

The constellations included in different schemes of study will vary of course; but those in the zodiac have special claims to consideration, for through them runs the course of the Moon and bright planets. As regards the number to be required, it is far better to recognize easily, from the characteristic grouping of a few stars some thirty or more, no matter how they are placed with regard to the horizon, than to have a minute and detailed acquaintance with eight or ten. Exhaustive treatment is not necessary for thoroughness and accuracy, and while striving earnestly to attain the latter, we should not hold with too painful effort to scientific formality. There must be room for the opera-glass and the beauties it reveals in clusters and nebulæ. There must be time for the myths and legends that have gathered about the constellations since the childhood of the race. Knowledge that comes through the gateway of pleasure possesses vital force.

SMITH COLLEGE OBSERVATORY,
NORTHAMPTON, Mass.

SOME DETAILS OF THE RECENT SOLAR CYCLE.

ROSE O'HALLORAN.

FOR POPULAR ASTRONOMY.

To those who have made a continued study of the solar surface during the years just past, the large sun-spots of October were a

tardy though effective signal that the intermittent period when spots are few and faint had passed away. An unspotted photosphere will now be a rare spectacle to telescopic vision.

Ruling the motions of Earth and planets by the attraction of its enormous mass, redeeming them from perpetual gloom with its radiation, the potent center of the solar system is nevertheless itself dominated by an unknown force so effective and unfailing in its operations that scientific interest has been keenly aroused during the last half century. Observations dating from 1610 established the fact that a large area of the solar surface is profusely spot-strewn for a few consecutive years, a condition invariably followed by a gradual decrease, until even months may pass of umblemished photospheric whiteness. These alternate conditions, known as the sunspot maximum and minimum, form a cycle generally lasting about eleven years and from one to two tenths. Though the extremes are in marked contrast, the boundary between them is not sharply defined nor has it a permanently midway position, the minimum being frequently the more prolonged.

That the surface of a vaporous and intensely heated body, more than a million times the size of the Earth, should be in a state of tumultuous disturbance accords with the known laws of heat and gravitation; but when it was found that solar tempests announce their presence by a deep-hued stain, show a distinct preference for certain zones of the Sun, observe unexplained laws as to differing rates of speed across the disk and maintain a fairly punctual period of increase and decline, the cause of these peculiarities became one of the foremost of astronomical problems.

Among many diverse theories the following receive the most favorable consideration: The dark areas may be the result of a downpour of passing meteors; or, in the climax of colliding currents on the seething surface, vapors may be cast forth, and on descending again in a state of comparative coolness, seem dark by contrast; or, violent whirlpools may frequent the zones most suited for cyclonic formation, and by suction bring down volumes of cooler matter from above. None of these theories however, account for the various complexities noticeable, while the eleven year period seems the most insolvable of Sun mysteries. Several astronomers, notably M. Loewy, the present Director of the Paris Observatory, ascertained many years ago that the positions of the planets, especially Jupiter the largest and Mercury and Venus the nearest to the Sun, yielded some evidence of co-operation in the periodicity of solar disturbance. Modern recognition of tidal effects among the heavenly bodies gives renewed force to

this theory. That Jupiter's time of revolution, nearly twelve years, would chiefly sway the photospheric tide is what might be inferred in such a case; and though maxima do not always correspond with the perihelion distance of the ruling planet, this may be a required compromise with the conflicting attraction of lesser tide-raisers. If it be that the circling planets thus waken tempestuous tides on the vaporous luminary, then our Earth can claim an humble share in the sublime process of Sun painting.

Of late years, maxima and minima have been carefully studied in detail, as thus only can further enlightenment be obtained, and as every locality is more or less subject to cloudiness, the combined records of several telescopists are generally requisite for a complete cycle of observation.

The following brief account, based on solar studies with a four-inch Brashear refractor, contains some of the characteristics of the two-fold period just completed.

An interruption of some length in the record, due to a journey to observe the eclipse of 1900, having occurred during the sunspot minimum, causes little material change in the outline.

According to a recent careful revision of sunspot data published by Professor Wolfer of France, the minimum preceding this just past was at its extreme stage of unspottedness during the first months of 1890, and as a corresponding stage did not occur until the summer of 1902, this solar cycle has been unusually prolonged. The last maximum showed its approach towards the end of 1891, continuing the three following years with little abatement, but though a slight renewal of disturbance was noticeable since September, 1902, it was only recently, twelve years later, that the corresponding stage of a returning maximum was clearly indicated.

My recorded observations were commenced on the first of November, 1891. The critical period in the career of an average spot being its first invasion of photospheric whiteness, one aim of these observations has been to note the number of times that this was seen to have occurred.

A disfigured area whether stained by one spot or by many is classed as one solar storm when the sprinkling does not extend beyond twenty-five degrees of the Sun's surface which being about the limit of the largest spots, gives some clue as to the probable range of a single disturbance. This method, though giving a far lower numerical result than if each section of a discoloration were counted, avoids including any spot more than once. From November the 1st, 1891, to the same date of the present year,

1903, the Sun was observed and the results recorded on 2,982 days, and according to the method adopted, 811 spotted areas were seen on the disk during that time. Two-thirds of the disturbances occurred within the first five years, the remainder being distributed over the ensuing years with decreasing frequency until September, 1902, when a slight but distinct increase of activity set in. During the maximum and minimum between 1879 and 1890, the spottedness of the surface south of the Sun's equator was more than double that of the northern zones, according to Comstock's text-book of astronomy; and from November, 1891, to this present November, 1903, solar storms have also been fewer in the northern hemisphere, but in the lesser disparity of seven to ten. Owing to misleading perspective effects at certain seasons, this estimate was deduced from 567 eruptions distinctly beyond equatorial zones, in which latter, accurate measurement of solar latitude is difficult. Of the entire number of spotted areas, namely 811, about forty sufficiently conspicuous to be visible under favorable circumstances without magnifying power may be classed as large; while solar tempests which from depth of hue combined with immense extent may be called giant spots stained the glowing orb to the distinct gaze of the world at large on four notable occasions. The first, one of the largest on record, measuring 150,000 miles in length and 75,000 in breadth, appeared inside the southeast limb on the 4th of February, 1892; the second assumed nearly equal dimensions when it ploughed the southern hemisphere in the beginning of August, 1893; the third with compact umbra and enormous penumbra tinged the southern zones in September, 1898, while the interesting formation of last October, the initial footprint of a returning maximum, lingered near the southerly border of the sunspot region from the 5th to the 17th of the month.

Terrestrial storms of air or ocean convey no adequate idea of the reality of these tumultuous battlefields of heat and motion on the vaporous Sun. To state that a spot cavity is ten times the diameter of the Earth, that our globe would be consumed to the centre if in contact for one minute with even the darkest umbra, and perhaps in the fury of contending currents might be ejected thousands of miles upward is but a restricted outline of the possibilities of solar agitation. Dwarfed by a distance of 93,000,000 of miles, monster discolorations of every shape have penned their stormy history again and again on the photospheric tablet, but as yet these hieroglyphics of the Sun have remained partly unread. The recent great sunspot, the largest in five years, reap-

peared in due time on the first of November and, though decreased in size, an additional outbreak in the rear rendered the group again visible to the naked eye as it crossed the disk. There

GREAT SUNSPOT OF 1903.
Oct. 11, 10h 30m A. M.

is good evidence that many of the larger spots were of long duration and came round to view more than once, but complete identification is difficult on account of change of form and position when on the unseen side of the rotating orb. Another feature of

A PENUMBRAL SPOT OF GREAT LENGTH.
1896 Sept. 14, 1h 20m P. M.

the cycle was the occasional disconnected stream of average eruptions from east to west revealing a wide distribution of activity. The most conspicuous case was in May, 1894, when three-fourths of the solar circumference was wreathed in spots from twenty to thirty degrees apart; but the lesser displays of streaminess thrice in 1895, once in 1896, and once in 1898, were also remarkable.

A specially interesting detail in a floating cavity of the photosphere is an indication that its dark depths form a whirlpool ac-

Jan. 14. Jan. 15. Jan. 19.
CYCLONIC SUNSPOT 1892.

cording to the theory of M. Faye, the French scientist. A cyclonic

tendency was noticed in several spots, the most remarkable being those of January 1892 and April 1899.

As early in the maximum years as August, 1894, an unspotted condition of the disk was again seen, the 25th of that month bringing a more unblemished surface to view than had appeared in two years and ten months. Thenceforth a spotless disk be-

GREAT SUNSPOT OF 1892.
Feb. 8 (Noon).

came more frequent, the culmination being eighty-six days distributed throughout 1901, and one hundred and forty-seven days throughout 1902. Of these latter, from June the 12th, to September the 11th, the surface was in a state of unusual quietude; occasional cloudy days however breaking the positive evidence that three months of continued inactivity had existed. From 1897 to 1901, zones not far from the Sun's equator were chiefly the scene of the diminishing disturbance, but within the last two years, higher latitudes resumed activity, which scattering of forces is frequently a pressage of returning maxima. The present renewal of a spotted condition is opportune. Though much information has been gained in the last fifty years some important points may need to be unlearned, as the marvelous properties of radium, and its incomprehensible relation to helium recently discovered by Sir William Ramsey, open possibilities as to solar heat-light and radiation unthought of heretofore.

THE STUDY OF THE VARIABLE STARS. X.
U CEPHEI—ITS LIGHT-VARIATIONS.

PAUL S. YENDELL.

FOR POPULAR ASTRONOMY.

The variations of U Cephei, and their type, were detected by Ceraski in 1880, and announced by him in the *Astronomische Nachrichten*, Vol. 97, col. 319. At that time only five stars of the Algol type were known, the last one previously discovered having been U Coronæ, found by Winnecke in 1869.

A discovery of the kind was much rarer at that time than it is now, and naturally excited much interest among those astronomers who occupied themselves with the variable stars. Many observers at once turned their attention to the new variable, and Glasenapp, Wilsing, Knott, Schmidt, Pickering, the Baxendells, senior and junior, and others, published numerous observations during the early years.

I took up the watch on the star in 1888, when the early close attention to it had somewhat relaxed; and since that time, no year has passed during which I have not made more or less observations of it, though one or two have gone by without my having recorded any observed minimum.

The main peculiarity of the light-curve was at once noticed, a peculiarity which it was the second star to exhibit, the first being S Cancri, but which is now so common as almost to constitute a sub-type by itself.

The work of the early observers, however, was for the most part directed to the investigation of its elements of variation, rather than to the course and character of its light-changes. Knott's numerous observations, extending from the time of the star's discovery until 1889, are mostly confined to the three hours on either side of the minimum, and very few of them were made during the time of ths star's normal brightness.

The earliest mean light-curve of U Cephei known to me is Pickering's, published in 1881, in the *Proceedings of the American Academy of Arts and Sciences*, Vol. XVI. It was baeed on about three hundred photometric observations made at the Harvard College Observatory. A discussion of the star's variations, including a mean light-curve, was published by Wilsing in 1884 (*Astronomische Nachrichten*, 2569). In 1889, Chandler (*Astronomical Journal*, Vol. IX, p. 49), published a discussion of the star's elements of variation, with "Spring" and "Autumn" mean curves, and a comparison of the same with those of Wilsing and Pickering, previously published.

Since the date of Chandler's paper, the only mean light-curve of our star that has come to my knowledge is that of Bohlin, reprinted from the *Nachrichten* in No. 93 of this publication.

Early iu the nineties I began to obsèrve U Cephei for the definite purpose of accumulating a mass of material sufficient for the formation of a mean light-curve of a somewhat definitive character. My minimum limit was placed at a thousand observations, and my intention was to secure as many of the Spring as of the Autumn curve. Observations were made whenever convenient, not

limited to the determination of minima, and especial efforts were made to get as many as might be at the beginning and end of the light-changes, where the observations are usually difficult and scanty.

Mostly from conditions dependent on the weather, it was not found practicable to secure as many observations of the Spring curve as of the Autumn one, and at the close of the observations of 1902, of eleven hundred and seventy-five observations only two hundred and eighty-six belonged to the Spring curve.

I began the reductions for the mean curves in the early part of 1902. I had intended to use the Harvard Photometry scale of magnitudes, as being the only photometric measures available for stars of all the magnitudes included in the range of the variable. Measures of the comparison-stars used were kindly furnished for the purpose by Professor Pickering. But tue values of the stars *d* and *b* (see Table of Comparison-stars) in these measures were discordant with their relative values according to both my own light-scale, formed from twelve years' observations, and that of Knott; and after reducing a considerable number of observations I found that the form of the curve near the minimum would be seriously distorted from this cause. The use of the Harvard magnitudes was thereupon abandoned.

Very shortly after the reductions had been suspended for this reason, and when I had almost decided upon the use of my provisional magnitude-scale previously used, formed from my own light-scale, Dr. Muller, of the Potsdam Astrophysical Observatory, very kindly offered to make measures of these comparison-stars for the purpose of my work. This offer I gladly accepted, and in Angust 1902 he sent me his results. His measures proved quite accordant with my light-scale, so that simple relations between them were readily established, and the work was resumed.

The comparison-stars and light-scale used are as follows: The first column of the table shows the notation used; the second, headed DM, their Durchmusterung numbers; the third, P, their magnitudes according to the Potsdam measures; and the fourth, Lt., my own step-scale, formed from all my observations to 1900, July 4, and retained in these reductions because in my judgment the later observations would not have sensibly changed it.

	DM	P	Lt.
	°	m	St.
k =	81 13	6.58	31.9
e =	18	7.43	24.4
f =	30	8.04	19.3
g =	27	8.53	14.8
h =	29	8.57	14.0
a =	80 21	8.93	9.2
b =	22	9.17	4.9
d =	81 22	9.29	1.9
e =	80 23	9.44	0.0

By the above light-scale, the value of a step is $0^m.114$ from *k* to *g*, and $0^m.052$ from *g* to *c*, being nearly twice as great among the brighter stars as among the fainter ones, but pretty constant in each group.

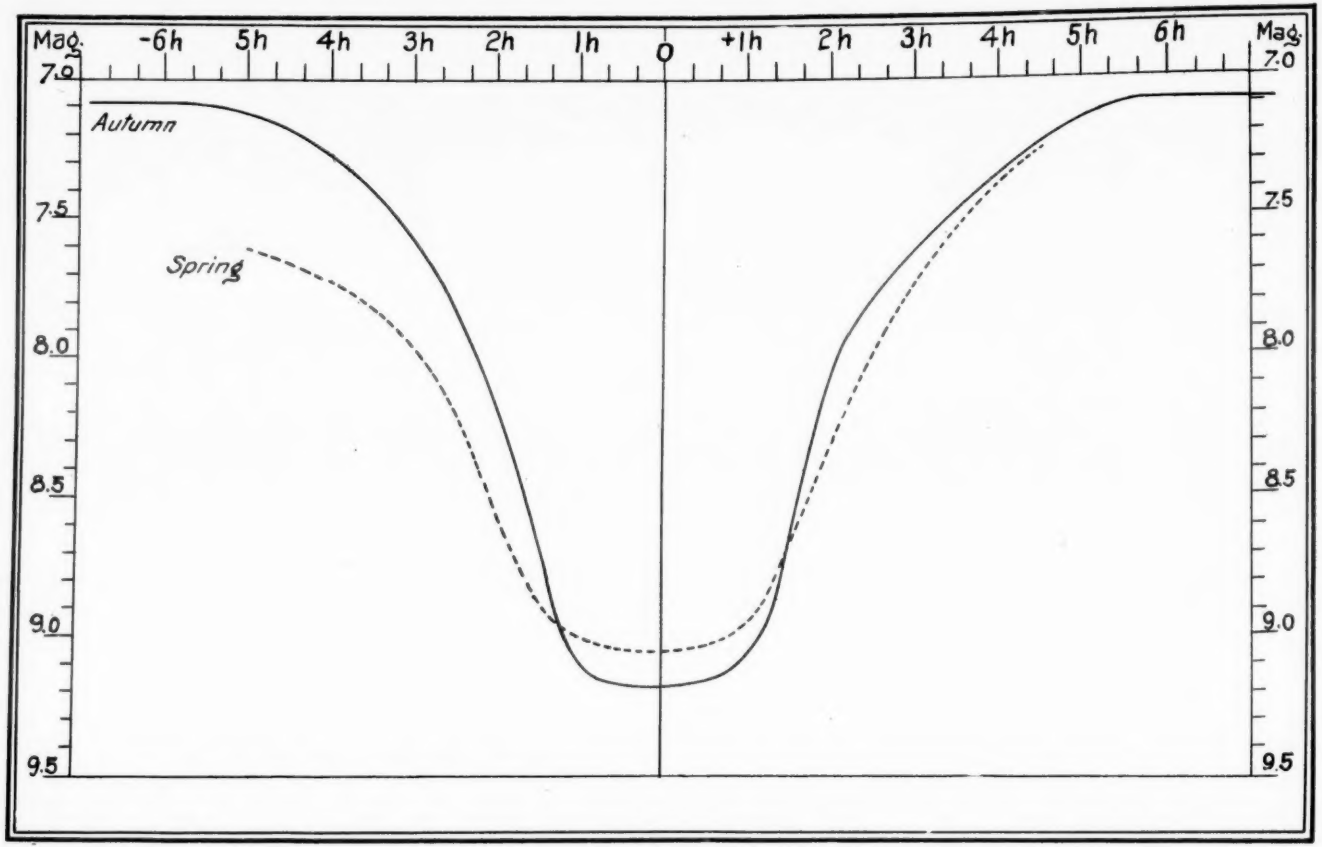
I am now fully convinced that the apparent difference between the "Spring" and "Autumn" curves of the star is purely subjective. Knott's separation of the minima into sets of odd and even epochs is contradicted by the fact that in Chandler's curves above alluded to, these groups are interchanged. Whereas Knott's even minima fell in the Spring, Chandler's, on account of the relative longitude of his place of observation, came in the Autumn, and *vice versa*. But Chandler's results for Spring and Autumn are respectively the same as Knott's. The former (*loc. cit.*) calls attention to the possible subjective nature of the phenomenon.

I have lately had occasion to reduce a number of series of observations of U Cephei made by different observers, ranging in time from the date of the discovery of variability down to the end of the year 1902, and find that in nearly all the series since Chandler's the minima observed in the Spring have been the odd, and in the Autumn the even epochs. In all these series except my own, the Spring minima are the fainter, by varying amounts. In my own series they are the brighter; but the difference steadily decreased as my precautions to avoid subjective errors became more and more sedulous, and as my experience with the star grew, until in the minima from 1898 to 1902 it almost wholly disappears. Besides, the asymmetry of the curve, reversed in the Spring and Autumn series of all the observers, almost entirely disappears in this group, especially in the much more fully observed Autumn curve.

The details of all the above facts may be found fully stated in my paper on the light-changes of U Cephei, published in the *Astronomical Journal*, No. 551.

The elements on which the present curves are based are provisional. They satisfy my observations at least as well as any yet proposed. The departure from Chandler's elements of 1897 began about 1894, and has gone on increasing until in the Autumn of 1902 the minima were nearly three hours late. (See also Hartwig's VJS Ephemerides, for 1902, p. 269, and 1903, p. 285).

It was necessary therefore, to find elements which would fairly represent the observed dates, and the following, suggested by Chandler in 1901, satisfy my observed minima, with an average residual of rather less than nine minutes.



MEAN LIGHT CURVES U CEPHEI.

Elements.

1880 June $23^d\ 7^h\ 43^m.5$, G. M. T., $2^d\ 11^h\ 49^m\ 44^s.7$ E.

As the difference between the two curves is undoubtedly subjective, and due to the varying presentation at different hour-angles of the group formed by the star and its comparison-stars, it seems that the dividing line between the two groups should be drawn at that angle at which these disturbances disappear. This occurs at hour angles $2^h\ 24^m$ West and $9^h\ 36^m$ East.

The line passing through these two hour-angles was accordingly adopted as the critical line, and all the observations made in hour-angles east of it were used in the formation of the East or Autumn curve, and those west of it for the Spring or West curve.

In forming the mean curves, seven hundred and eighty-one observations were found available for the East, or "Autumn" curve, and two hundred and sixty-eight for the West or "Spring" curve. At the normal light there were eighty-five observations in East hour-angle, and eighteen in West, one hundred and three in all; from these twenty-three normals were formed.

In forming the normals for the Autumn curve, as far as practicable twenty observations were used for each normal, so as to give them approximately equal weights; but at the beginning and end of the period of change, the observations were less numerous, and the normals therefore formed from smaller groups. The corresponding normals for the Spring curve were formed from ten observations each.

The following table presents the normals from which the curves were formed. The column $T - t$ contains the interval from the computed time of minimum; M the magnitude; o the number of observations which make up the normal; and v the departure of each normal from the curve as drawn.

Tne last fifteen normals in the Autumn table, and the last eight in the Spring one fall in the time of the star's normal light. They give no indication of any real fluctuation in brightness during that part of the period, the average departure from a mean of $7^m.09$ being $0^m.03$, and the probable error of a single normal $0^m.02$. The residuals are pretty impartially distributed over the whole of this part of the star's period, and their signs show a fairly satisfactory alteration.

The mean minimum light shown is for the Autumn curve $9^m.18$, and for the Spring curve $9^m.06$. Neither curve shows any correction to the computed time of minimum.

AUTUMN.

T − t h	m	M	o	v	T − t h	m	M	o	v
− 4	55.8	7.14	10	+ .01	+ 0	15.9	9.16	20	− .01
4	31.4	7.38	10	+ .20	0	34.6	9.18	20	+ .03
4	13.0	7.12	8	− .11	0	48.4	9.10	20	− .02
3	44.8	7.37	15	+ .05	0	56.6	9.11	20	+ .03
3	34.7	7.41	14	+ .04	1	6.0	9.05	20	+ .02
3	17.3	7.40	15	− .05	1	13.8	8.96	20	+ .02
3	4.1	7.46	20	− .08	1	20.9	8.75	20	− .10
2	52.0	7.67	20	+ .04	1	26.3	8.83	20	+ 10
2	40.1	7.82	20	+ .09	1	33.9	8.56	20	− .02
2	22.8	7.86	20	− .06	1	39.7	8.39	20	− .01
2	10.5	8.12	20	+ .06	1	47.9	8.33	20	+ .09
1	59.8	8.11	20	− .08	1	56.6	8.08	20	− .02
1	51.6	8.43	20	+ .12	2	4.6	7.97	20	− .02
1	44.2	8.41	20	.00	2	21.2	7,81	20	− .03
1	37.5	8.55	20	+ .02	2	48.8	7.69	20	.00
1	30.7	8.56	20	− .08	3	31.8	7.48	19	.00
1	21.8	8.84	20	+ .02	4	56.3	7.13	4	− .03
1	16.2	8.87	20	− .07	5	44.5	7.11	6	+ .02
1	8.3	9.06	20	+ .04	7	9	7.09	3	.00
1	1.2	9.08	20	− .01	9	18.5	7.10	4	+ .01
0	52.9	9.14	20	+ .01	13	58.1	7.09	6	.00
0	41.0	9.16	20	.00	16	26.8	7.05	5	− .04
0	28.1	9.16	20	− .01	20	16.2	7.09	5	.00
− 0	16.9	9.23	20	+ .06	21	35.6	7.09	9	.00
+ 0	8.1	9.17	20	− .01	25	11.7	7.12	10	+ .03
27	44.5	7.14	6	+ .05	46	6.1	7.10	4	+ .01
29	26.1	7.10	6	+ .01	49	17.8	7.98	11	− .01
32	34.8	7.06	4	− .03	52	27	7.03	3	− .06
+ 42	18.3	7.07	6	− .02	+ 54	11.3	7.05	3	− .04

SPRING.

T − t h	m	M	o	v	T − t h	m	M	o	v
− 4	52.1	7.62	10	.00	− 0	1.6	9.05	10	− .01
3	45.3	7.77	10	+ .01	+ 0	16.1	9.03	10	− .03
3	18.5	8.24	10	+ .38	0	36.1	9.04	10	− .02
2	36.0	8.09	10	− .03	1	11.8	8.81	10	− .10
?	30.6	8.10	10	− .10	1	28.0	8.65	10	− .05
2	20.2	8 35	10	+ .04	1	49.7	8.48	10	+ .05
1	59.7	8.56	10	.00	2	8.4	8.29	10	+ .07
1	47.4	8.64	10	+ .08	2	27.7	7.96	10	− .05
1	42.1	8.74	10	− .03	2	49.8	7.82	7	+ .01
1	31.7	8.81	10	− .05	4	34.3	7·28	2	.00
1	23.9	8.84	10	− .04	8	3	7.06	2	− .03
1	14.9	8.96	10	+ .01	19	13	7.11	2	+ .02
1	5.3	8.95	10	− .04	20	31	7.11	2	+ .02
0	57.0	9.03	10	+ .02	31	13	7.07	3	− .02
0	49.4	8.99	10	− .04	33	15	7.08	3	− .01
0	43.7	9.06	10	+ .02	44	23.5	7.06	2	− .03
0	26.4	9.07	10	+ .02	46	27	7.11	2	+ .02
− 0	9.8	9.09	10	+ .03	+ 47	26	6.96	1	− .13

According to these curves, the duration of the star's light-variation is longer than it has hitherto been stated. It is from $-5^h\ 40^m$ to $5^h\ 40^m$, and therefore occupies $33^h\ 20^m$. These limits are well-defined in the Autumn curve, but the beginning of the Spring curve is much less satisfactory. From some unknown cause, doubtless subjective, it is much distorted to about $-2^h\ 30^m$.

The readings from these curves are as follows:

	Autumn			Spring		
	Before	After		Before	After	
T − *t*	M	M		M	M	T − *t*
h m						h m
−5 40	7.09	7.09				
20	7.10	7.11				
5 0	7.12	7.15		7.60		5 0
4 40	7.16	7.21		7.64		4 40
4 20	7.21	7.29		7.67	7.30	4 20
4 0	7.27	7.37		7.72	7.39	4 0
3 40	7.34	7.45		7.78	7.49	3 40
3 20	7.44	7.54		7.86	7.61	3 20
3 0	7.57	7.64		7.97	7.74	3 0
2 40	7.73	7.73		8.10	7.90	2 40
2 20	7.95	7.85		8.31	8.10	2 20
2 0	8.19	8.05		8.56	8.32	2 0
1 40	8.49	8.40		8.78	8.56	1 40
1 20	8.84	8.85		8.93	8.80	1 20
1 0	9.10	9.07		9.00	8.97	1 0
0 40	9.17	9.14		9.04	9.02	0 40
0 20	9.17	9.17		9.06	9.04	0 20
0 0	9.18	9.18	Minimum.	9.06	9.06	0 0

With this exception, the differences between the two curves are: the comparative flatness of the Spring curve, its brighter minimum, and its asymmetry as compared with the Autumn curve.

The latter is so far the more fully observed and better made out curve, made from observations taken at far the more favorable season of the year, and the precautions to avoid subjective errors have been so unremitting, that it seems to me to be probably a very good approximation to the star's real light-curve. Its departures from actual symmetry are very slight in the best determined part, up to $7^m.5$, and at $9^m.08$, $8^m.65$, and $7^m.73$ they disappear altogether.

If we form a symmetrical curve from the means of each pair of ten-minute readings, the probable error of one of these readings is $0^m.025$, while their mean departure from the symmetrized curve is $0^m.027$,

Assuming that the minimum light is constant from -1^h to $+1^h$, the probable error of one of the nine normals is $0^m.018$, while their mean departure from their mean value is, as in the other part of the curve, $0^m.027$. So that the indications are very strong, that these assumptions are good approximations to the actual state of things, although numerically they fall short of actual proof.

After fifteen years' constant and careful observation of U Cephei, the impression remaining on my mind is, that the course of the star's light-changes is that which would result from an annular eclipse; a symmetrical light-curve with inflection increasing with its proximity to the minimum, and an interval of constant minimum light.

DORCHESTER, 1903, Dec. 12.

THE MARKINGS AND ROTATION PERIOD OF SATURN.

W. F. DENNING, F. R. A. S.

The conspicuous markings observed in the northern hemisphere of Saturn during the present opposition have greatly encouraged observation of, and interest in, a beautiful object. The complaint has sometimes been made that this planet, though forming an unique picture, attractive in the highest degree, yet lacks variety and the evidence of similarly great and abundant changes which render the study of Jupiter so entertaining. But the aspect of Saturn during the past summer has led to a modification of opinion on this point, and has proved that "the ringed orb" is occasionally the scene of extensive disturbances, and that the vapors surrounding him are travelling in parallel currents, differing in their relative velocities even more widely than those on the surface of Jupiter. In future years it is fair to assume, therefore, that Saturn will be more closely studied than hitherto. Apparently he has been somewhat neglected in the past; his ring-system has usually occupied chief notice, and perhaps diverted attention from more important phenomena displayed on the ball. In viewing this planet the observer's principal aim has been to obtain glimpses of the crape ring, Encke's division in the outer ring, or certain of the satellites, and thus the configuration in detail of the globe has escaped critical survey.

Astronomical records furnish comparatively few instances of irregular markings on Saturn, and when objects of this kind have been detected they do not appear to have always been followed with the necessary persistency. Sir W. Herschel was the first to discover evidences of rotation, and to determine a value for it. He narrowly watched certain inequalities in a quintuple belt, visible in the planet's southern hemisphere in 1793, December, and 1794, January, and wrote in the *Philosophical Transactions* for the latter year, "I can at present announce the reality of the quick rotation by means of 154 revolutions of the planet," and "We may conclude that the period is exact to $\pm$ 2 min., and we need not hesitate to fix the rotation of Saturn upon its axis as $10^h\ 16^m\ 0^s.44$."

Schroeter, of Lilienthal, made many observations of this planet more than a century ago, and derived rotation periods of $11^h\ 40^m\ 30^s$, $11^h\ 51^m$, and rather more than 12^h, from various markings he followed, but these results are very doubtful, and astronomers have never attached any weight to them.

Schwabe, of Dessau, observed markings in 1847, and a round bright spot near the S. limb was noticed by Busch and Luther in 1848. Certain dark patches were seen by Bond in 1848 and 1854, and re-observed by De la Rue in 1856. Lassell, Jacob, Coolidge. Dawes, Secchi and a few others also detected spots at about the same period.

Lassell wrote in 1857, January 8: "There are certainly chronic changes of great magnitude occasionally occurring on the face of this planet."

Dawes stated* in 1858, January: "I have observed a well-marked light spot in the S. hemisphere of Saturn which I estimated to be at about 40° or 50° of S. latitude. It was nearly in the axial line on January 11, at $10^h\ 30^m$ G. M. T., and again on January 14, $11^h\ 20^m$, on both occasions a little past it."

Lassell viewed Saturn with a magnificently defined image in his 20-feet reflector of 20 inches aperture, powers 430 and 650, on 1858, April 17, just before 9 P. M., and said,† "Near the preceding limb, and a little south of the equatorial dark belt, was a brighter portion, too large to be called a spot yet sufficiently defined or marked out to be useful in determining the rotation of the planet."

The white spot seen by Dawes on 1858, January 11 and 14, and that observed by Lassell on April 17 of the same year, were probably identical objects, with a rotation period of nearly $10^h\ 25^m$. Dawes' two observations sufficiently prove that the marking exhibited a rate not differing greatly from $10^h\ 24\frac{1}{3}^m$.

Professor Asaph Hall attentively studied Saturn during the fourteen years from 1875 to 1889 with the great Washington refractor of 26 inches aperture by Alvan Clark, and found that the ball of the planet presented very few changes, the most remarkable being the outbreak of an equatorial white spot, first seen on 1876, December 7. Professor Hall said that "on poor nights when the image is blazing and unsteady we can see and can imagine many strange things about this wonderful object." The white spot was watched from 1876, December 7, to 1877, January 2, by Professors Hall and Eastman at Washington, by Mr. A. G. Clark at Cambridgeport, and was also seen by several other American observers. A number of transits were secured, and from these it appeared that at intervals of three days the spot arrived at the planet's central meridian 16 minutes earlier than before. Profes-

* *Monthly Notices*, XVIII., p. 72.

† *Ibid*, XVIII., p. 231.

sor Hall found for the time of rotation $10^h\ 14^m\ 23^s.8$, with a probable error of only 2.3 secs.*

In 1891 and three following years a considerable number of bright and dark spots near the equator and in certain other latitudes of Saturn were discerned by Mr. A. S. Williams, of Brighton, with a 6½-inch reflector. The results were discussed and summarized in *Monthly Notices*, LIV., p. 298–314, and LV., p. 354–67.† The rates of the various objects differed slightly, ranging between about $10^h\ 13^m$ and $10^h\ 16^s$, but they appeared to present a satisfactory agreement with the earlier values of Herschel and Hall. It is only fair to mention, however, that several other experienced observers‡ employing powerful telescopes quite failed to see any spots on Saturn at about the same period. It is not, however, our intention to discuss the question whether planetary markings can be easily seen in a 6½-inch telescope, and their individual forms traced while instruments of 36 inches and less fail to show any vestige of such objects. The remarkable efficacy of small telescopes in revealing planetary detail has often been admitted, but comparisons at the observatories of Mount Hamilton, Princeton, Chicago, and elsewhere have proved the undoubted superiority of large instruments.

In 1896 and 1897, M. Antoniadi, using the 9¾-inch refractor of the Juvisy Observatory, observed dusky condensations on the north equatorial belt, and from these he ascertained the rotation period as a little more than $10^h\ 14^m$.

During the last quarter of a century Professor Hall's determination has been regarded as a standard value for the rotation of Saturn. True, it was based on few observations extending over twenty-seven nights only, and upon an object obviously variable, for while at first it was round and 2 or 3 seconds of arc in diameter, it resolved itself at last into a bright streak.

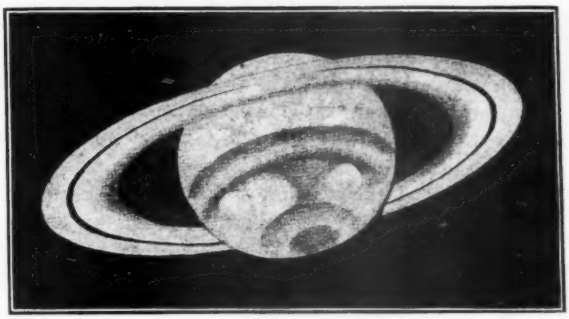
The planet has been traversing the southern signs of Scorpio and Capricornus during the last few years, and its low position in the sky has had the usual effect in impairing the definition so much that observers in northern latitudes have not been successful in detecting any irregular markings on the disc. The present opposition has, however, provided developments of very important and interesting character. Professor Barnard was examining

* *Astronomische Nachrichten*, No. 2146.

† See also *Ast. Nach.*, No. 3051.

‡ Professor Barnard, writing in 1903, June, says that during all the observations he had previously made of Saturn he had never seen any marking that could be used for determining the rotation period.

Saturn on June 15, 21^h, G. M. T., with the 40-inch Yerkes refractor, when he discovered a decidedly marked white spot halfway between the central meridian of the planet and the following limb. Clouds came over, but the marking was recovered on June 23rd, when its passage across the central meridian occurred at $21^h\ 42^m$, G. M. T. It was seen again on June 24th, and the central transit observed at $18^h\ 58^m$, G. M. T. On July 1st the writer, at Bristol (unaware of previous observations), noticed a bright spot on Saturn which must have been central at about



SATURN, 1903, AUGUST 21, 11^h.

$14^h\ 1^m$, though it had passed to some distance west of the central meridian when first seen. This object was subsequently assumed to be identical with Barnard's spot of June 23rd, for eighteen rotations of $10^h\ 14\frac{1}{2}^m$ would accord well with the interval elapsed between the pair of transits, but further observations disclosed the surprising fact that the new markings were moving far too slowly to be consistent with the usually accepted rate of Saturn's rotation. Graff, of Hamburg, pointed out in *Ast. Nach.* that the period of Barnard's spot, deduced from a few of the earlier observations, was about $10^h\ 39^m.01$, while Solà, of Barcelona, from more materials, found the value $10^h\ 38^m.4$. There have been several spots visible, both light and dark, and the chief one, first seen at the middle of June, has been watched at Bristol during the past five months, and its mean rotation period has been as nearly as possible $10^h\ 38^m$. There is indication that the motion of this particular object has been slightly accelerated, but the evidence is not conclusive on the point. The other markings distributed along the same latitude show slight differences of period, and at the end of September they had become difficult objects.

In June the principal spot was large, and very much brighter than the light north-temperate zone in which it was placed. The

usual observational discordances have become apparent as regards the transit times, the form, dimensions, and aspect of the marking. Barnard on June 23 found the length, E. and W., 2″.6. H. C. Wilson, at Northfield, Minn., on July 1 measured the length, 3″.93, and width, 2″.36, while Graff on June 26 gave the proportions 5″ by 3″. The spot is both followed and preceded by dusky patches stretching from the north equatorial belt to the polar shading. As seen by Wilson on July 1 it appeared surrounded by a narrow dark line, but the observer suggests that this may have been the effects of contrast. The north latitude of the spot, according to a measure by Barnard on June 23, was 36°.4, while Wilson determined it on July 1 as 31°.1.

Present indications are that the disturbance has, in its main features, practically subsided. Its lessons cannot fail to be of considerable interest. It has afforded the clearest proofs of a north-temperate current rotating 23½ minutes slower than the equatorial current as determined by Professor Hall from his spot of 1876-7. A comparison of the relative velocities leads us to the following curious deductions. The equatorial spots are moving so much faster than the north-temperate spots that they gain some 800 miles per hour upon them, and complete a circuit of Saturn relatively to their positions in about 12 days. A terrestrial hurricane is supposed to have an extreme velocity of about 100 miles per hour, but the wind currents on Saturn appear to be incomparably swifter. And the rapid equatorial drift on Saturn is probably persistent within small limits of variation like the equatorial current of Jupiter, which, during the last 25 years, has only varied between $9^h\ 50^m$ and $9^h\ 50\frac{1}{2}^m$.

On the latter planet the ordinary north-temperate spots rotate in $9^h\ 55^m\ 54^s$, which is about 5½ minutes slower than the equatorial spots. Both on Jupiter and Saturn, therefore, the mobile vapors on or near the equator are streaming along with abnormal velocity, outstripping other markings to N. and S., and also, probably, the actual rotatory movement of the immense spheres below. There may be occasional exceptions, it is true, as, for instance, the very rapidly moving dark spots which temporarily marked the north-temperate region of Jupiter in 1880 and 1891.

The closer scrutiny of Saturn in future years is desirable, and it seems well assured from the interest awakened by the prominent signs of activity recently displayed on the planet's surface. The investigation is a promising one. It may appear curious, on reflection, that comparatively little has been already accomplished in elucidating the visible surface phenomena of this wonderful orb,

forming as he does the most charming picture in the sky. Perhaps Saturn has sometimes been regarded as an object more suitable for exhibition than for sedulous research. In any case it is to be hoped that he will now receive more fitting recognition, for his belts and occasional spots merit as much attention as the variegated scenery of Jupiter or the wonderful and complicated canaliform aspect of Mars.

Previous observations suggest that the rotation of the equator of Saturn is $10^h\ 14\frac{1}{2}^m$, of the south-temperate region $10^h\ 25^m$, and of the north-temperate region $10^h\ 38^m$. But the materials are altogether too scanty for safe deductions. Many new observations are required of well-marked equatorial and south-temperate spots. We may have to wait years for the apparition of these, for Saturn's aspect is often serene and smooth, without any obvious irregularities in the belts and zones.

Postscript, Nov. 15.—Including my latest observations here with a 10-inch reflector, powers 312 and 332, the mean rotation periods of three of the best observed spots on Saturn work out as follows:

Object.	Interval of Observations. Days.	Rotations.	Period. h	m	s
Barnard's White Spot	138	310	10	37	52.4
White Spot	132	295	10	37	42.0
Dark Spot	120	270	10	37	56.4

The period appears therefore to be a little less than $10^h\ 38^m$, and bears out the suggestion previously made that the velocity has been accelerated.—From *Knowledge*, December, 1903.

IMPORTANT ASTRONOMICAL WORK IN PROGRESS.

W. W. PAYNE.

A brief look over the wide field of astronomical activity in all the different parts of the world shows that its devotees are busy workers, and that the great problems which they are trying to solve are neither few nor commonplace; but that they involve results that will probably be far reaching in utility and consequence for science in general and astronomy in particular.

The most important piece of work which has claimed the attention of more than a dozen observatories in different countries for the past few years, is the Photographic Chart of the Heavens. The photographic part of the work has been completed, and the meridian observations of reference stars is now in progress. Next comes the preparation of all this mass of matter for publication. Astronomers generally will be interested to know how well this

part of the great task will be done. It will be of large consequence to astronomy if the publication is worked out completely, and put into some orderly form, easy of reference, compact, inexpensive and without unnecessary details. There are some large observatories that will want this work to be made just as complete as possible, and probably such will not be satisfied with anything less than all that the voluminous records contain. Observatories generally, however, will probably prefer an edition of results for working uses that may possibly be less expensive yet very useful and within the reach of many astronomers.

Eros and the solar parallax is another of the pending problems of astronomy that has engaged the attention of more astronomers during the last two years than any other. There are two or three things in this work that are especially noteworthy. One is the trial of photography for the first time in the study of one of the most difficult problems known to astronomy. The plan has been to photograph the planet Eros while passing near the Earth, as often as possible, to obtain its apparent position among the stars very closely, to compare the same with the apparent positions of the planet obtained in like manner by other observatories in Europe; and by this means to obtain the parallax of Eros. This being correctly known the astronomer is enabled to obtain the parallax of the Sun, the unit of measurement for most distances in the solar system.

Some astronomers have used the equatorial telescope with the micrometer attached to find the place of Eros while passing stars well suited for the purpose of such measurements. This is a certain method of work, if a competent astronomer does it, and he can get enough such measures to ensure the accuracy of the results he is trying to get.

It is to be hoped that these two kinds of work on the parallax of Eros will be, each, so fully and faithfully tried, that the usefulness of photography for this kind of record may have a satisfactory and a crucial test. In order that the test may satisfy the most exacting astronomer that will scrutinize the work when it appears in contrast, these two kinds of work ought to have been performed by the same astronomer; for the personal equation under such circumstances might be an uncertain quantity. When it is remembered that the whole purpose of this Eros campaign is to lessen by some certain amount the error of the Sun's parallax which is now only about two one-hundredths of a second of arc, any one can see that only the best work of the most skillful will be of any use for an increase of our present knowledge of the Earth's distance from the Sun.

During this last year astronomers have been engaged very generally in measuring and reducing the photographic plates, and this work now seems to be nearing completion. We may expect soon to receive the results of those that have been in the lead of this work, and later that which is more definitive in kind and extent.

The radial motion of stars is another interesting theme for present astronomical research. The great observatories with instruments peculiarly adapted to this kind of observation have been busy at it, as results recently published plainly show. Potsdam, Yerkes and Lick Observatories have been deservedly prominent in this line of work.

The variable stars are claiming their full share of attention at the hands of experienced observers in this country, as well as elsewhere, and, one of the promising things about this comparatively new line of work is the fact that it has interested and continuously employed so many amateurs in recent years, that a goodly number of able observers have come to the front, and many of them are doing very creditable work.

The new line of observation in regard to variables is that pertaining to star clusters. Professor S. I. Bailev of the Arequipa Station of Harvard College Observatory was the first to call attention to this interesting field of study. He found 132 variables in Messier 3 in Canes Vanatici, 113 in cluster 5273 of the New General Catalogue of Nebulæ, 85 in Messier 5, out of 750 stars, and 122 in the great cluster ω Centauri. These are a few illustrations of the work in this direction which is only fairly begun. There is a considerable list of suspected variables that are now under observation which are not yet classed as known variables, because work on them has not yet gone sufficiently far. Some of the more prominent of these stars are, (according to J. E. Gore, in his new book entitled, The Stellar Heavens):*

δ Ursæ Majoris, which is the faintest star of the well-known seven, and has long been suspected of a variation of light; α Hydræ, a reddish star, which the ancient Chinese named "the Red Bird," and which the Arabians called the solitary one, beeause of its isolated position south of the "Sickle" in Leo. By the Harvard measures its magnitude is rated 2.02; λ Draconis is another which Mr. Gore himself observed from 1876 to 1891 during which time he noted variations in brightness to the extent of nearly a whole magnitude. "It was rated a third to fourth magnitude by Ptolemy, Al Sufi, Argelander and Heis, but Houzeau

* See notice of this book elsewhere in this number.

made it 4.5 in 1875. This star is of an orange hue, ond the spectrum of the third type." A few others are named because some amateur observers may not know of them, and because they are good objects for study by this class of observers.

α Serpentis
ε Pegasi
83 Ursæ Majoris
ζ Piscis Australis
η Crateris
α Eridani
γ Geminorum
α Ophiuchi
α Sagittarii
β Leonis
ζ Ursæ Majoris
γ Virginis
ο Persei

Speaking about variables in general Mr. Gore says that it is a remarkable fact that such stars, except in a few cases, so far as known show any parallax or proper motion, which probably means that they lie, in space, at very great distances from the Earth.

For the last few years, one of the most perplexing themes in the study of meteoric streams has been the behavior of the Leonid showers. The leading authority in this branch of astronomy in the world at the present time is undoubtedly W. F. Denning of Bristol, England. His observational work and writings respecting every important feature of many meteoric streams are eagerly sought by all observers in America and very much used for guidance and instruction. As a means of setting before our readers some interesting points in the last November display of the Leonid Shower, we give below his report of it, as published in December *Observatory*, p. 458:

"Those who, notwithstanding the disappointments of previous years, stood out watching the sky on November 15 were amply rewarded by seeing a really fine display of shooting-stars. The Leonid radiant rose at about 10^h 15^m, and soon afterwards occasional meteors of the usual aspect were directed from it. At midnight one meteor in every four or five minutes shot from the "Sickle." The display therefore had become well defined and fairly rich, but during the next two hours there was no great rise in the rate of apparition. Between 14^h and 16^h, however, the number rapidly increased, and an observer in a good open situation could enumerate about one meteor per minute. The next two hours afforded a further development, and between 17^h and 18^h the horary rate was variously estimated by different observers as from 120 to 250. My position at Bristol was not a good one, buildings and trees partially obstructing the view, but I counted 42 Leonids in the quarter of an hour from 17^h 30^m to 17^h 45^m, and 15 Leonids in the five minutes 18_h to 18^h 5^m, after which the display exhibited a perceptible decline in the increasing twilight.

Nearly all the meteors left streaks, and they were generally bright, quite a large proportion being equal to 1st magnitude stars. Some of them were equal to Jupiter, and occasionally one would rival if not exceed Venus. The latter rose at $14^h\ 45^m$ followed by the waning crescent of the Moon at $15^h\ 47^m$, and the two objects formed a very attractive picture.

During minor displays of the Leonids, I have usually found the radiant a sharply defined position, but this was not the case on the occasion of the recent display. Some of the Leonids with foreshortened flights in or near the "Sickle" distinctly showed that no contracted focus would include their various directions. It was necessary, in fact, to adopt a radiant-area of about 6° or 7° in diameter, near the stars ζ and γ Leonis, and around the point $151° + 22°$ as a center.

During the night I saw traces of minor showers near μ Andromedæ, α Aurigæ, α-β Persei, ζ and κ Draconis, and α Leonis Minoris, but they were very feeble and scarcely determinable amid the swarm of Leonids. I should be very glad to receive duplicate observations of an exceedingly slow ζ Draconid recorded here on November 15 $15^h\ 41^m$, and of a very long-pathed, slow-moving meteor from a radiant-point low in the southern sky. The latter object appeared on November 15, $15^h\ 59^m$, and occupied five seconds in sailing along an arc of 45° from β Leonis to β Boötis.

The really rich phase of the Leonid shower must have been very short-lived. On November 14, 17^h to $17^h\ 45^m$, in a beautifully clear sky, I did not see a single Leonid, though there were five other meteors. On the night following November 16 I looked out at times when the firmament was sufficiently clear, but few meteors appeared, and the Leonid radiant gave very slight traces of continued action."

By looking over the pages of this number of our magazine and the next, as a whole, it will be interesting to the thoughtful reader to notice how much space is given to topics relating to the Sun and to the Moon, either in the form of books, articles or paragraph news. The work of making and printing large photograph atlases of the Moon during the last two years has gone forward at a remarkable pace. The work of the Paris Observatory, as already previously noticed, at length, in these pages, has taken the lead in this particular. But, just now comes to our table the large and splendidly printed volume, in quarto form, on the same theme, by Professor W. H. Pickering, the result of his recent expedition to Jamaica mainly for this purpose. This book has a fuller notice elsewhere in this issue.

One of the chief objects of this painstaking photograph work of the lunar surface seems to be a desire, on the part of astronomers, to make a full and careful record of it now for the sake of future comparisons. The former methods of such study consisted in elaborate drawings to the minutest detail often on a very large scale for the sake of making a historical record. But such a method necessarily involved the personal equation of the artist astronomer who had undertaken the task, and the result of that has been to cause an almost endless discussion of the merits and the accuracy of the very best lunar maps that were ever made in this way. The question now is will photography remedy or help to correct this troublesome defect in our knowledge on the subject of changes that may or may not be going on respecting the surface of the Moon. As far as we can see at present, the prospect does not seem to be very encouraging. There are advantages in photography for lunar study, especially the aid secured by it in making a general map of the Moon: but when we come to the task of showing minute details on a large scale, the photographic work so far is rather disappointing. Practical observers know that the trained eye, at the telescope, takes advantage of the fine conditions of seeing for scrutinizing details that no skill can draw, nor any photographic plate catch and hold for successful development. The future may give aid by furnishing more rapid plates, or, improved methods of development so that it may be possible both to differentiate and then to integrate the details of the entire surface of a quick or slow photographic plate, so as to make it reveal to the astronomer the truth, the whole truth and nothing but the truth of its witnessing power. We still work in the hope of realizing this grand possibility.

Astronomical Phenomena During 1904.

Eclipses.

There will be two eclipses of the Sun and none of the Moon. Neither of the solar eclipses will be of any astronomical importance the one being an annular eclipse and the other a total eclipse, the path of totality lying wholly over water. The following data are taken from the *American Ephemeris* for 1904:

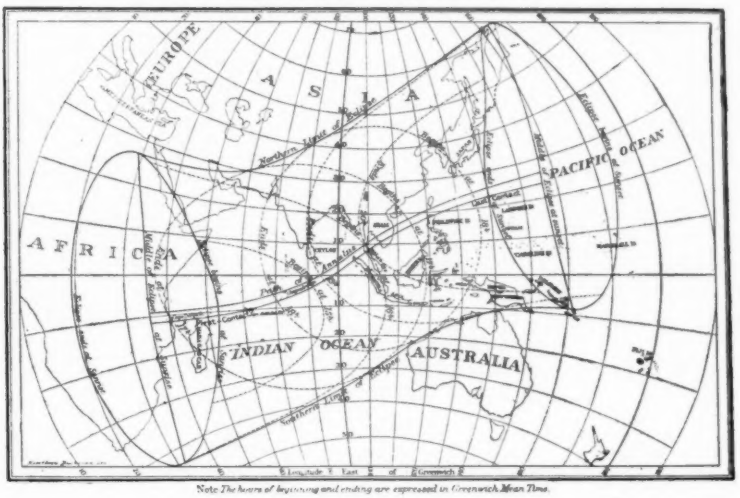
1. *An Annular Eclipse of the Sun*, 1904 March 16. The path of the annulus passes from the coast of Africa, just north of Madagascar, across the Indian Ocean, the Malay Peninsula and Siam, and ends in the Pacific Ocean southeast of Japan. As a partial eclipse it will be visible in the eastern part of Africa, the southern and eastern parts of Asia and on many of the islands of the Pacific Ocean.

ELEMENTS OF THE ECLIPSE.

Greenwich mean time of conjunction in right ascension, March 16, $17^h\ 45^m\ 39^s.1$

Sun and Moon's R. A.	$23^h\ 46^m\ 8^s.07$	Hourly motions $9^s.14$ and	$1^m\ 54^s.40$
Sun's Declination	$-1°\ 30'\ 8''.6$	Hourly motion	$+\ 0'\ 59''.3$
Moon's Declination	$-1\ 12\ 46\ .6$	Hourly motion	$+\ 9\ 21\ .4$
Sun's equa. hor. parallax	$8\ .8$	Sun's true semidiam.	$16\ 4\ .1$
Moon's equa. hor. parallax	$54\ 24\ .6$	Moon's true semidiam.	$14\ 49\ .6$

ANNULAR ECLIPSE OF MARCH 16TH 1904



Note. The hours of beginning and ending are expressed in Greenwich Mean Time.

CIRCUMSTANCES OF THE ECLIPSE.

	Greenwich Mean Time.	Longitude from Greenwich.	Latitude.
Eclipse begins	March 16 $14^h\ 36^m.5$	$52°\ 41'.7$ E.	$12°\ 58'.7$ S.
Central eclipse begins	16 15 44 .0	35 53 .6 E.	10 15 .3 S.
Central eclipse at noon	16 17 45 .7	95 44 .8 E.	6 20 .6 N.
Central eclipse ends	16 19 37 .6	157 3 .7 E.	25 12 .4 N.
Eclipse ends	16 20 45 .0	140 17 .4 E.	22 29 .7 N.

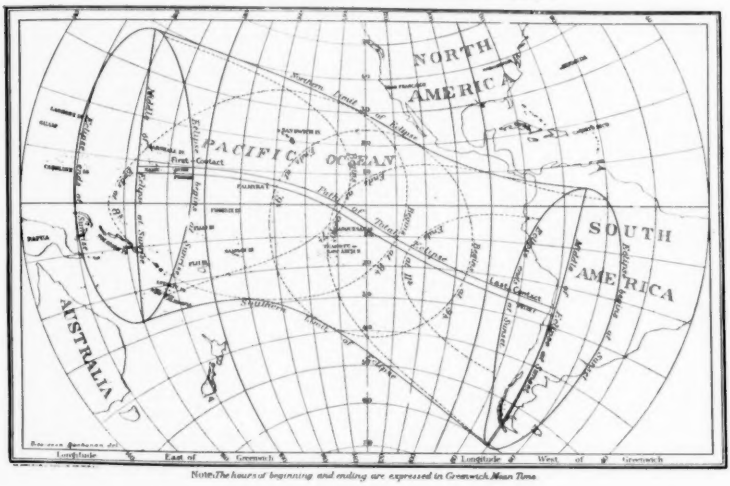
2. *A Total Eclipse of the Sun*, 1904, Sept. 9. The path of totality begins in the Pacific Ocean among the Marshall Islands and runs southeastward over the ocean, ending near the eastern boundary of Chili. In Chili the Sun will be just setting at the time of totality and the only other land touched by the umbra of the Moon's shadow is a few of the small islands of the Pacific. None of these islands is favorably situated for observing the eclipse, which is unfortunate, since the duration of totality of this eclipse is relatively long, amounting to $6^m\ 23^s$ at the maximum. This will be the opportunity of the astronomer, if there be one, who has at his command a private yacht, to locate himself in the path of the eclipse and observe the phenomena, unhampered by the necessity of attending to numerous instruments as in the ordinary eclipse. The longest duration of totality is a little south of the equator northeast of the Marquesas Islands.

ELEMENTS OF THE ECLIPSE.

Greenwich Mean Time of conjunction in right ascension, Sept. 9, $8^h\ 49^m\ 34^s.1$.

Sun and Moon's R. A.	$11^h\ 11^m\ 5^s.39$	Hourly motions	$9^s.00$ and $146^s.16$
Sun's declination	$+5°\ 14'\ 56''.3$	Hourly motion	$0'\ 56''.7$ S.
Moon's declination	$+5\ \ 4\ 30\ .7$	Hourly motion	$11\ 32\ .3$ S.
Sun's equa. hor. parallax	$8\ .7$	Sun's true semidiam.	$15\ 53\ .2$
Moon's equa. hor. parallax	$61\ 23\ .0$	Moon's true semidiam.	$16\ 43\ .6$

TOTAL ECLIPSE OF SEPTEMBER 9TH 1904



Note. The hours of beginning and ending are expressed in Greenwich Mean Time.

CIRCUMSTANCES OF THE ECLIPSE.

	Greenwich Mean Time.	Longitude from Greenwich.	Latitude.
Eclipse begins	September 9 $6^h\ 7^m.8$	$176°\ 19'.0$ E.	$11°\ 9'.3$ N.
Central eclipse begins	9 7 3 .0	162 49 .7 E.	7 53 .0 N.
Central eclipse at noon	9 8 49 .6	133 5 .2 W.	4 35 .1 S.
Central eclipse ends	9 10 25 .7	69 45 .2 W.	26 38 .0 S.
Eclipse ends	9 11 20 .9	83 11 .6 W.	23 21 .8 S.

THE PLANETS.

The apparent paths of the planets among the stars during 1904 are shown in the diagrams Figs. 1 and 2.

Mercury starts out at once on the closed loop in Capricorn and Sagittarius, being visible as evening planet during the first few days of January, coming to conjunction Jan. 16, and becoming visible as morning star during the first days of February. Thence its course will be eastward and northward, while on the farther side of the Sun, until in May the planet comes between Earth and Sun again, being visible as evening star in the latter part of April and morning star in the first half of June. This time its retrograde movement produces an S-shaped loop in the curve of its path, just a little way southwest from the Pleiades. The third inferior conjunction of the planet with the Sun occurs in September, when another closed loop is described in Leo and Virgo, and the planet will be visible as evening star in the latter part of August and as morning star in the last days of September and first of October. Still a fourth loop of Mercury's path is begun in December but is only half completed at the end of the year. If the reader will

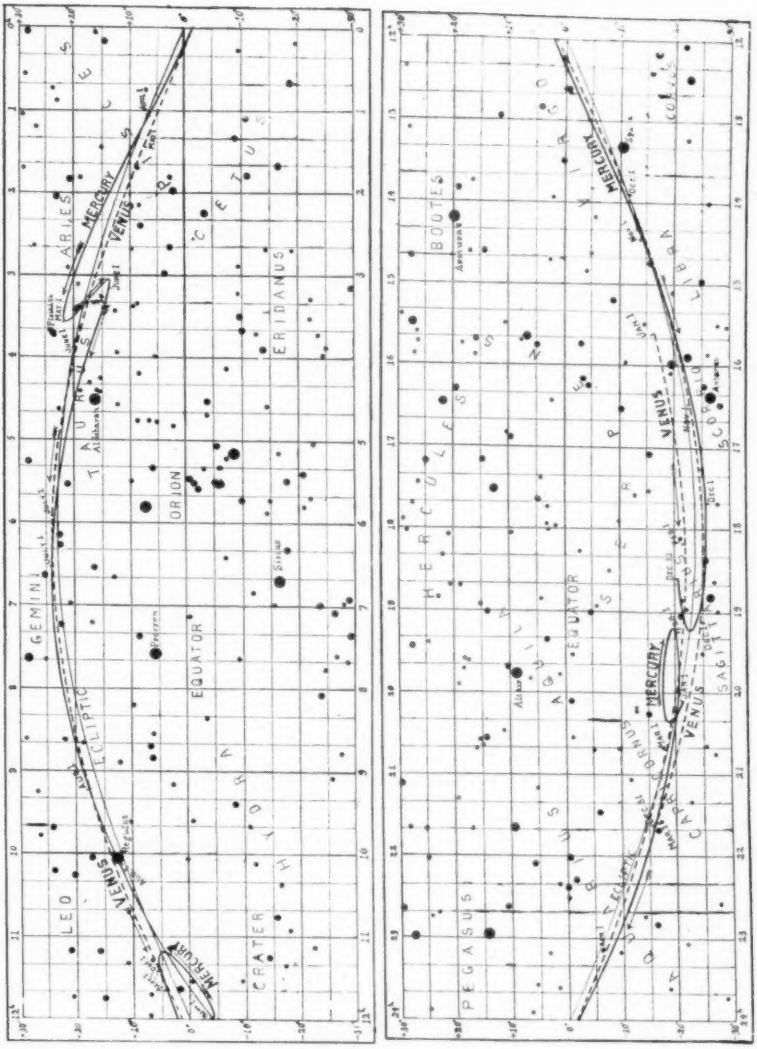


FIG. 1.—DIAGRAM SHOWING THE APPARENT MOVEMENTS OF THE PLANETS MERCURY AND VENUS DURING 1904.

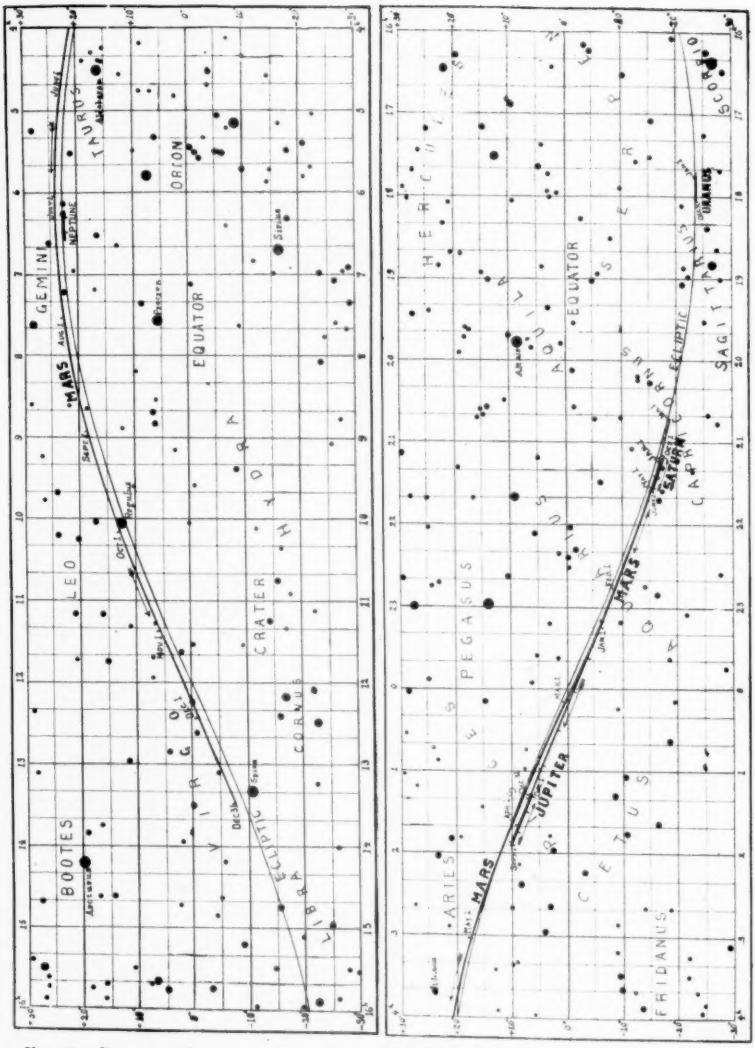


FIG. 2.—DIAGRAM SHOWING THE APPARENT MOVEMENTS OF THE PLANETS MARS, JUPITER, SATURN, URANUS AND NEPTUNE DURING 1904.

compare the diagrams of the path of Mercury in the January numbers of POPULAR ASTRONOMY for several years past, he will see that there is a great variety in the form of the apparent loops described by the planet. This is caused by the shifting of the points of conjunction westward around the planet's orbit; and as Mercury's orbit is inclined 7° to plane of the Earth's orbit, its movement is seen at a different angle from the Earth at each conjunction.

The dotted line showing Venus' apparent path for the year contains no loop since Venus does not come into inferior conjunction with the Sun this year. She will be at superior conjunction on July 7, and will be visible as evening star during the autumn and winter.

Mars also has no retrograde movement this year. His course begins in Capricorn near Saturn and follows the ecliptic closely, ending in Virgo not far from Spica. In the past month Mars has passed by Saturn and the two planets made a beautiful spectacle together. Their brightness was as nearly equal as one could estimate, the only difference being in the color of the apparent twin stars. In February 1904 Mars will pass Jupiter, the conjunction occurring Feb. 25 at 11 P. M., Central Standard time. Mars will then be 30′ north of Jupiter. Unfortunately at that hour of the night the two planets will be below the horizon in the United States.

Jupiter moves northeastward from Aquarius into Pisces, reaching 10° 12′ north declination in August, and coming to opposition Oct. 18. His movement will be retrograde from about the middle of August to the middle of December.

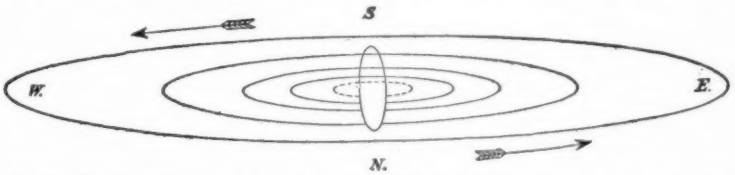


FIG. 3.—DIAGRAM SHOWING THE APPARENT MOVEMENTS OF JUPITER'S SATELLITES IN 1904.

The planet will be in fine position for observation in the autumn and early part of next winter. The diagram Fig. 3 shows the apparent movement of the satellites of Jupiter during the opposition of 1904.

Saturn describes a similar course to that of Jupiter, but is low down, in the

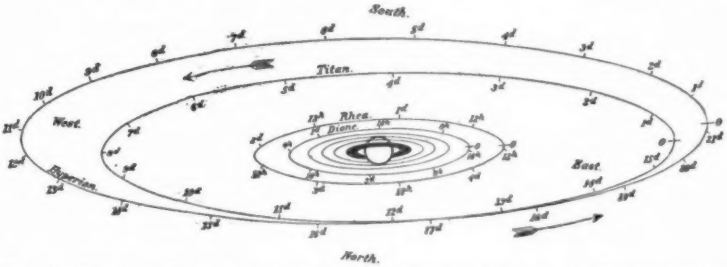
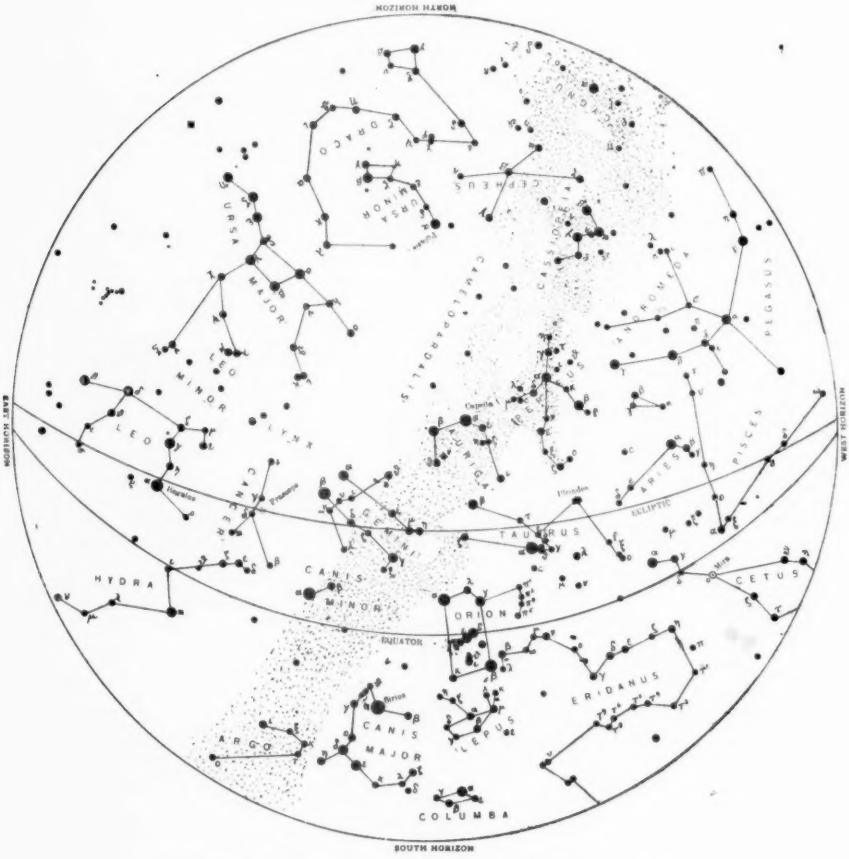


FIG. 4.—DIAGRAM SHOWING THE APPARENT MOVEMENTS OF THE SATELLITES OF SATURN IN 1904.

constellation Capricorn, so that at no time will the planet be in favorable position for observation in our latitude. The motion is direct until June 1, then ret-

rograde until Oct. 19, and after that direct. The apparent movements of seven of Saturn's satellites are shown in the diagram Fig. 4.

Uranus' course in Sagittarius is so short that its details cannot be shown on the chart plainly, but the motion is direct along the ecliptic until April 4, retrograde after that time until Sept. 5, then again direct. The planet will be always at too low an altitude for good observations in our latitude.



THE CONSTELLATIONS AT 9 P. M. FEBRUARY 1, 1904.

Neptune's course is also short, in the constellation Gemini. Starting westward it will pass the star μ Geminorum Jan. 16, the planet being then 15′ south of the star. It will continue to retrograde until March 14, then turning eastward will again pass the star μ on May 9, being then only 10′ south of the star. It will move eastward until Oct. 11 and then retrograde for the remainder of the year.

COMETS.

Of the six comets whose return was due in 1903 only one, Brooks 1889 V, has at this writing been detected. In 1904, four comets whose periods are well determined are expected to return to perihelion, but only one of these will be so situated as to make us feel confident of its rediscovery.

1. Winnecke's Periodic comet is due at perihelion Jan. 21, 1904, according to the computations of C. Hillebrand (*A. N.* 3907), but will be in unfavorable position for observation, almost directly behind the Sun.

2. D'Arrest's comet is due about February 1, but is also on the farther side of the Sun and so not likely to be seen.

3. Tempel's second periodic comet is due at perihelion early in November. Its position will not be as favorable as at the last apparition in 1899, and since it was then very faint, there is some doubt about its being visible this year. If found at all it will probably be during the summer months.

4. Encke's famous comet will reach perihelion at the close of the year and will probably be visible as early as September. In November the comet will be comparatively near the Earth and should become quite a conspicuous telescopic object.

Phases of the Moon.

Washington Mean Time.

New Moon.			First Quarter.			Full Moon.			Last Quarter.		
	h	m		h	m		h	m		h	m
.....			.....								
Jan. 16	22	38	Jan. 25	3	33	Jan. 2	12	39	Jan. 9	4	2
Feb. 15	17	56	Feb. 23	18	0	Jan. 31	23	25	Feb. 7	16	48
Mar. 16	12	31	Mar. 24	4	28	Mar. 1	9	40	Mar. 8	7	52
Apr. 15	4	45	Apr. 22	11	46	Mar. 30	19	36	Apr. 7	0	45
May 14	17	50	May 21	17	10	Apr. 29	5	28	May 6	18	42
June 13	4	2	June 19	22	2	May 28	15	46	June 5	12	44
July 12	12	19	July 19	3	40	June 27	3	15	July 5	5	46
Aug. 10	19	50	Aug. 17	11	19	July 26	16	34	Aug. 3	20	54
Sept. 9	3	34	Sept. 15	22	4	Aug. 25	7	54	Sept. 2	9	50
Oct. 8	12	17	Oct. 15	12	46	Sept. 24	0	41	Oct. 1	20	44
Nov. 6	22	28	Nov. 14	7	27	Oct. 23	17	48	Oct. 31	6	5
Dec. 6	10	38	Dec. 14	4	59	Nov. 22	10	4	Nov. 29	14	30
						Dec. 22	0	53	Dec. 28	22	38

OCCULTATIONS.

The list of occultations, given as visible at Washington, in the American Ephemeris, numbers just 100. The list for January was given in the last number of POPULAR ASTRONOMY. That for February is as follows:

Occultations Visible at Washington.

Date. 1904.	Star's Name.	Magnitude.	IMMERSION. Washington M.T. h	m	Angle f'm N pt. °	EMERSION. Washington M. T. h	m	Angle f'm N pt. °	Duration. h	m
Feb. 1	*o* Leonis	3.8	17	53	115	18	47	292	0	54
6	2 Libræ	6.3	18	12	107	19	34	292	1	22
6	B.A.C. 4772	6.6	19	04	73	20	08	322	1	04
8	49 Libræ	5.6	12	44	129	13	38	262	0	54
22	W.B. ii, 1033	5.9	10	14	28	10	50	315	0	36
24	B.A.C. 1526	5.8	11	24	73	12	22	288	0	58
25	130 Tauri	5.5	6	49	106	8	09	250	1	20

METEOR SHOWERS.

The following list contains the more brilliant showers, from a list of 90 meteoric showers whose radiant points are given by Mr. W. F. Denning in the *Companion to The Observatory:*

Date.	Radiant. α	Radiant. δ	Remarks.
Jan. 2-3	230°	+ 53°	Swift; long paths.
Apr. 20-21	270	+ 33	Swift.
May 1-6	338	− 2	Swift; streaks.
July 28	339	− 11	Slow; long.
Aug. 10-12	45	+ 57	Swift; streaks. The Perseids.
Oct. 18-20	92	+ 15	Swift; streaks.
Nov. 14-16	150	+ 22	Swift; streaks. The Leonids.
Nov. 23-24	25	+ 43	Very slow; trains. The Andromedes.
Dec. 10-12	108	+ 33	Swift; short.

The Perseids, with a maximum on Aug. 11, are visible for a considerable period and their radiant exhibits a motion, to the E.N.E. among the stars of about 1° per day. Its position for July 19 should be α 19°, δ + 50°, and on Aug. 16 α 53°, δ + 58°.

COMET AND ASTEROID NOTES.

New Asteroids.—The following have been added to the list of new planets since our last note:

	Discovered By	At	Local M. T. h m	R. A. h m	Decl. ° ′	Mag.
1903 MW	Wolf	Heidelberg Oct. 27	12 01.2	3 18.9	+ 14 08	13.5
MX	Wolf	" Nov. 14	8 02.8	3 04.9	+ 10 52	13.2

Numbering of Recently Discovered Asteroids.—In *A. N.* 3914 Dr. J. Bauschinger assigns the following numbers, to recently discovered asteroids whose orbits have been computed:

(507)	1903 LO	Dugan	Heidelberg
(508)	" LQ	"	"
(509)	" LR	Wolf	"
(510)	" LT	Dugan	"
(511)	" LU	"	"
(512)	" LV	Wolf	"

The planet 1903 LP was found to be identical with (406) [1895 CB]. 1902 JO, which had been assigned the number (489) has been shown to be identical with (470) Kilia. The number (489) will be assigned to the planet 1902 JM, for which the elliptic orbit computed is uncertain.

Definitive Elements of Comet 1894 I (Denning).—Dr. P. Gast, in the "Mitteilungen der Grossh. Sternwarte zu Heidelberg II," gives the results of a definitive computation of the orbit of Denning's periodic comet 1894 I from all the accessible observations. He obtains the following elements:

EPOCH 1894 MARCH 28.0 BERLIN M. T.

$$M_0 = 6^\circ\ 10'\ 45''.20 \pm 0''.117$$
$$\pi = 130\ 37\ 9\ .33 \pm 4\ .511$$
$$\Omega = 84\ 22\ 20\ .38 \pm 5\ .801$$
$$i = 5\ 31\ 45\ .96 \pm 0\ .239$$
$$\phi = 44\ 17\ 55\ .50 \pm 1\ .889$$
$$\mu = 478''.29684 \pm 0''.00958$$
$$\log a = 0.5802061$$

These elements make the period 7.419 years. The comet was not observed at its return in 1901 because of its unfavorable position. The next return will be near the close of 1908, when its position will be quite favorable for observation.

VARIABLE STARS.

Minima of Variable Stars of the Algol Type.

[Greenwich Mean Time beginning with midnight. The hours greater than 12 are those of the afternoon. To obtain Eastern Standard time subtract 5 hours; for Central Standard subtract 6 hours, etc.]

U Cephei.

	d	h
Feb	2	13
	5	1
	7	13
	10	1
	12	12
	15	0
	17	12
	20	0
	22	12
	24	23
	27	11
	29	23

Z Persei

Feb.	3	13
	6	14
	9	16
	12	17
	15	18
	18	20
	21	21
	24	22
	28	0

Algol.

Feb.	2	0
	4	21
	7	18
	10	14
	13	11
	16	8
	19	5
	22	2
	24	22
	27	19

λ Tauri.

Feb.	3	17
	7	16
	11	14
	15	13
	19	12
	23	11
	27	10

R Canis Maj.

Feb.	1	17
	2	20
	4	0
	5	3
	6	6
	7	9
	8	13
	9	16
	10	19
	11	22
	13	2

R Canis Maj.

	d	h
Feb.	14	5
	15	8
	16	11
	17	15
	18	18
	19	21
	21	0
	22	4
	23	7
	24	10
	25	13
	26	17
	27	20
	28	23

RR (R^2) Puppis

Feb.	2	14
	8	0
	13	11
	18	21
	24	7
	29	18

S Cancri

Feb.	6	22
	16	10
	25	21

S Antliæ.

Feb.	1	5
	2	4
	3	3
	4	3
	5	2
	6	1
	7	1
	8	0
	8	23
	9	23
	10	22
	11	21
	12	21
	13	20
	14	19
	15	19
	16	18
	17	17
	18	17
	19	16
	20	15
	21	15
	22	14
	23	13
	24	13
	25	12

S Antliae

	d	h
Feb.	26	12
	27	11
	28	10
	29	10

S Velorum.

Feb.	5	22
	11	20
	17	19
	23	17
	29	16

δ Librae.

Feb.	2	3
	4	11
	6	19
	9	3
	11	11
	13	19
	16	3
	18	10
	20	18
	23	2
	25	10
	27	18

U Coronae.

Feb.	2	13
	6	0
	9	11
	12	22
	16	9
	19	20
	23	6
	26	17

R Aræ.

Feb.	1	15
	6	2
	10	12
	14	22
	19	8
	23	18
	28	5

U Ophiuchi.

Feb.	1	16
	2	12
	3	8
	4	4
	5	0
	5	21
	6	17
	7	13
	8	9
	10	1

U Ophiuchi.

	d	h
Feb.	10	21
	11	18
	12	14
	13	10
	14	6
	15	2
	15	22
	16	18
	17	14
	18	11
	19	7
	20	3
	20	23
	21	19
	22	15
	23	11
	24	7
	25	4
	26	0
	26	20
	27	16
	28	12
	29	8

Z Herculis.

Feb.	1	16
	3	14
	5	15
	7	14
	9	15
	11	14
	13	15
	15	14
	17	15
	19	13
	21	15
	23	13
	25	15
	27	13
	29	14

RX (X^2) Herculis.

Feb.	1	15
	2	13
	3	10
	4	7
	5	5
	6	2
	6	23
	7	21
	8	18
	9	15
	10	13
	11	10
	12	7

RX (X^2) Hercul.

	d	h
Feb.	13	5
	14	2
	15	0
	15	21
	16	18
	17	16
	18	13
	19	10
	20	8
	21	5
	22	2
	22	23
	23	21
	24	18
	25	16
	26	13
	27	10
	28	8
	29	5

RV (V^2) Lyræ.

Feb.	4	5
	7	0
	11	20
	15	10
	18	15
	22	5
	25	20
	29	10

U Sagittæ.

Feb.	1	7
	4	16
	8	1
	11	10
	14	19
	18	4
	21	14
	24	23
	28	8

SY (X^3) Cygni.

Feb.	2	0
	8	0
	14	0
	20	1
	26	1

SW (V^3) Cygni.

Feb.	5	2
	9	16
	14	6
	18	20
	23	9
	27	23

Minima of Variable Stars of the Algol Type.—Continued.

WW Z[4]) Cygni.		WW (Z[4]) Cygni.		W Delphini.		Y Cygni.		Y Cygni.	
d	h	d	h	d	h	d	h	d	h
		Feb. 25	14	Feb. 24	10	Feb. 8	9	Feb. 20	9
Feb. 1	10	29	1	29	6	9	17.	21	17
4	21	W Delphini.		Y Cygni.		11	9	23	9
8	8					12	17	24	17
11	18	Feb. 5	5	Feb. 2	9	14	9	26	9
15	5	10	0	3	17	15	17	27	17
18	16	14	19	5	9	17	9	29	9
22	3	19	15	6	17	18	17		

Variable Stars of Short Period not of the Algol Type.

	Minimum.		Maximum.			Minimum.		Maximum.	
	d	h	d	h		d	h	d	h
S Crucis	Feb. 1	16	Feb. 3	4	S Crucis	Feb. 15	18	Feb. 17	6
κ Pavonis	1	16	5	11	β Lyrae	15	22	19	0
SU Cygni	2	7	3	15	S Normae	16	10	20	20
S Muscae	2	11	5	22	T Crucis	16	21	18	22
V Centauri	2	11	3	22	RV Scorpii	17	9	18	18
β Lyræ	3	0	6	2	T Vulpeculae	17	6	18	16
S Trianguli Austr.	3	2	5	4	SU Cygni	17	16	19	0
δ Cephei	3	3	4	18	κ Pavonis	17	20	21	15
T Monocerotis	3	8	11	6	V Velorum	18	4	19	3
T Crucis	3	11	5	12	R Crucis	18	8	19	17
T Vulpeculae	4	1	5	10	T Velorum	18	16	20	1
ζ Geminorum	4	5	9	5	V Centauri	18	23	20	10
T Velorum	4	18	6	3	δ Cephei	19	6	20	21
V Velorum	5	1	6	0	S Crucis	20	10	21	22
W Geminorum	5	2	7	17	W Geminorum	20	14	23	5
RV Scorpii	5	3	6	13	V Carinae	20	15	22	19
SU Cygni	6	3	7	11	SU Cygni	21	12	22	20
S Crucis	6	9	7	21	T Vulpeculae	21	19	23	4
W Virginis	6	12	14	17	S Muscae	21	19	25	6
R Crucis	6	16	8	1	S Triang. Austr.	22	1	24	3
S Normae	6	16	11	2	β Lyrae	22	9	25	16
V Carinae	7	5	9	9	V Velorum	22	13	23	12
V Centauri	7	23	9	10	T Velorum	23	8	24	17
T Vulpeculae	8	12	9	21	RV Scorpii	23	8	24	18
δ Cephei	8	12	10	3	T Crucis	23	14	25	15
S Triang. Austr.	9	9	11	11	W Virginis	23	19	31	23
T Velorum	9	9	10	18	R Crucis	24	4	25	13
V Velorum	9	10	10	9	V Centauri	24	11	25	22
β Lyrae	9	11	12	18	ζ Geminorum	24	13	29	13
κ Pavonis	9	18	13	13	δ Cephei	24	15	26	6
SU Cygni	9	23	11	7	S Crucis	25	3	26	15
T Crucis	10	4	12	5	SU Cygni	25	8	26	16
S Crucis	11	1	12	13	κ Pavonis	25	22	29	17
RV Scorpii	11	4	12	14	S Normae	26	4	30	14
S Muscae	12	3	15	14	T Vulpeculae	26	5	27	14
TX Cygni	12	6	17	9	V Velorum	26	22	27	21
R Crucis	12	12	13	21	TX Cygni	26	23	32	2
W Geminorum	12	20	15	11	V Carinae	27	8	29	12
T Vulpeculae	12	22	14	7	T Velorum	27	23	29	8
V Centauri	13	11	14	22	W Geminorum	28	8	30	23
V Velorum	13	19	14	18	S Triang.Austr.	28	9	30	11
δ Cephei	13	21	15	12	β Lyrae	28	20	31	22
V Carinae	13	22	16	2	SU Cygni	29	5	30	13
T Velorum	14	1	15	10	RV Scorpi	29	9	30	19
ζ Geminorum	14	9	19	9	S Crucis	29	19	31	7
X Cygni	14	18	21	13	V Centauri	29	23	31	10
S. Triang. Austr.	15	17	17	19					

Approximate Magnitudes of Variable Stars Dec. 10, 1903.

[Communicated by the Director of Harvard College Observatory, Cambridge, Mass.]

Name.	R. A. 1900. h	m	Decl. 1900. °	′	Magn.	Name.	R. A. 1900. h	m	Decl. 1900. °	′	Magn.
T Androm.	0	17.2	+26	26	14*f*	R Camel.	14	25.1	+84	17	9*d*
T Cassiop.	0	17.8	+55	14	8	R Bootis	14	32.8	+27	10	12*d*
R Androm.	0	18.8	+38	1	10*i*	S Librae	15	15.6	−20	2	*s*
S Ceti	0	19.0	− 9	53	10*d*	S Serpentis	15	17.0	+14	40	*f*
W Cassiop.	0	49.0	+58	1	*f*	S Coronae	15	17.3	+31	44	12*f*
S "	1	12.3	+72	5	12*d*	S Urs. Min.	15	33.4	+78	58	8
R Piscium	1	25.5	+ 2	22	12*d*	R Coronae	15	44.4	+28	28	6
R Trianguli	1	31.0	+33	50	6	V "	15	45.9	+39	52	*u*
U Persei	1	52.9	+54	20	8	R Serpentis	15	46.1	+15	26	*s*
R Arietis	2	10.4	+24	36	8*i*	R Herculis	16	1.7	+18	38	*s*
o Ceti	2	14.3	− 3	26	9	R Scorpii	16	11.7	−22	42	*s*
S Persei	2	15.7	+58	8	9*d*	S "	16	11.7	−22	39	*s*
R Ceti	2	20.9	− 0	38	12*d*	U Herculis	16	21.4	+19	7	*s*
U "	2	28.9	−13	35	12*d*	R Ursae Min.	16	31.3	+72	28	9
R Persei	3	23.7	+35	20	8	W Herculis	16	31.7	+37	32	10*i*
R Tauri	4	22.8	+ 9	56	12*i*	R Draconis	16	32.4	+66	58	*f*
S "	4	23.7	+ 9	44	14*f*	S Herculis	16	47.4	+15	7	*s*
R Aurigæ	5	9.2	+53	28	9*i*	R Ophiuchi	17	2.0	−15	58	*s*
U Orionis	5	49.9	+20	10	12*d*	T Herculis	18	5.3	+31	0	8*i*
R Lyncis	6	53.0	+55	28	9*d*	R Scuti	18	42.2	− 5	49	*s*
R Gemin.	7	1.3	+22	52	11*d*	R Aquilae	19	1.6	+ 8	5	*f*
S Canis Min.	7	27.3	+ 8	32	8*i*	R Sagittarii	19	10.8	−19	29	*s*
R Cancri	8	11.0	+12	2	8*d*	S "	19	13.6	−19	12	*s*
V "	8	16.0	+17	36	11*i*	R Cygni	19	34.1	+49	58	8*d*
S Hydrae	8	48.4	+ 3	27	9*i*	RT "	19	40.8	+48	32	9*d*
T "	8	50.8	− 8	46	10*i*	X "	19	46.7	+32	40	6*d*
R Leo. Min.	9	39.6	+34	58	9*d*	S Cygni	20	3.4	+57	42	*f*
R Leonis	9	42.2	+11	54	8*d*	RS "	20	9.8	+38	28	7
R Urs. Maj.	10	37.6	+69	18	12*d*	R Delphini	20	10.1	+ 8	47	11*d*
R Comae	11	59.1	+19	20	*f*	U Cygni	20	16.5	+47	35	11
T Virginis	12	9.5	− 5	29	*f*	V "	20	38.1	+47	47	12*i*
R Corvi	12	14.4	−18	42	10*i*	T Aquarii	20	44.7	− 5	31	*f*
Y Virginis	12	28.7	− 3	52	*f*	R Vulpec.	20	59.9	+23	26	8*i*
T Urs. Maj.	12	31.8	+60	2	9*d*	T Cephei	21	8.2	+68	5	8*i*
R Virginis	12	33.4	+ 7	32	11*d*	S "	21	36.5	+78	10	8*i*
S Urs. Maj.	12	39.6	+61	38	9*d*	S Lacertae	22	24.6	+39	48	9*d*
U Virginis	12	46.0	+ 6	6	9	R "	22	38.8	+41	51	12*d*
V "	13	22.6	− 2	39	*f*	S Aquarii	22	51.8	−20	53	13*f*
R Hydrae	13	24.2	−22	46	*s*	R Pegasi	23	1.6	+10	0	11*d*
S Virginis	13	27.8	− 6	41	9*d*	S "	23	15.5	+ 8	22	9*i*
R Can. Ven.	13	44.6	+40	2	12*d*	R Aquarii	23	38.6	−15	50	8*i*
S Bootis	14	19.5	+54	16	8*i*	R Cassiop.	23	53.3	+50	50	11*i*

NOTE:—*f* denotes that the variable is probably fainter than the magnitude 13; *i*, that its light is increasing; *d*, that its light is decreasing; *s*, that it is near the Sun; *u*, that its magnitude is unknown.

Derived from observations made at the Halsted, McCormick, Eadie, Vassar College and Harvard Observatories, Dec. 10, 1903.

New Variable Stars 32-54.1903 Orion.—These are all in the great nebula of Orion and were announced by Professor Max Wolf in *A.N.* 3899. They were overlooked in our previous notes. Their positions for 1900.0 and their magnitudes are as follows:

Provis. Notation.	R. A. h	m	s	Decl. °	′	″	Mag.
32.1903	5	26	59.2	−4	31	26	14.0 — < 15
33.1903	5	27	13.6	−5	7	1	11.3 — 15.0
34.1903	5	27	16.6	−7	32	45	13.3 — 14.0
35.1903	5	27	45.0	−7	38	47	13.6 — < 14
36.1903	5	28	37.6	−5	16	17	13.8 — 15.0
37.1903	5	28	59.5	−4	52	3	13.0 — 15.2
38.1903	5	29	23.3	−6	40	16	13.0 — 15.0
39.1903	5	29	55.8	−4	44	16	12.5 — 14.0
40.1903	5	30	0.5	−5	50	49	12.5 — 14.0
41.1903	5	30	16.3	−5	50	36	12.0 — 14.5
42.1903	5	30	20.8	−4	49	45	12.7 — < 14
43.1903	5	30	27.1	−5	38	48	12.3 — < 14
44.1903	5	30	58.1	−4	51	15	12.8 — < 15
45.1903	5	30	58.9	−6	54	40	12.5 — 15.0
46.1903	5	31	8.4	−6	46	26	12.6 — < 14
47.1903	5	33	38.4	−7	19	14	13.5 — 15.0
48.1903	5	35	57.8	−8	8	32	13.0 — 15.0
49.1903	5	36	36.0	−4	11	17	9.8 — < 15
50.1903	5	30	39.4	−6	49	14	12.5 — < 14
51.1903	5	32	18.4	−3	35	15	13.0 — 14.0
52.1903	5	34	31.9	−4	57	26	12.5 — 13.2
53.1903	5	35	57.9	−8	7	43	12.8 — 13.9
54.1903	5	43	16.1	−5	43	36	12.7 — 13.5

The last five are designated as possibly variable; all the others as certainly variable.

Nomenclature of Newly Discovered Variable Stars.*

Provis. Notation A. N.	Name.	Position for 1900.0 R. A. h	m	s	Decl. °	′	Prec. 1900 R. A. s	Decl. ′
11.1903	R U Andromedæ	1	32	47	+ 38	9.5	+ 3.49	+ 0.31
15.1903	Z Cephei	2	12	48	+ 81	13	+ 7.81	+ 0.28
56.1903	RR Cephei	2	29	23	+ 80	42.3	+ 8.03	+ 0.27
14.1902	Z Persei	2	33	40	+ 41	46.1	+ 3.81	+ 0.26
22.1903	X Camelopardalis	4	32	36	+ 74	56	+ 7.68	+ 0.12
5.1903	RS Tauri	5	46	3	+ 15	51.3	+ 3.45	+ 0.02
1.1903	Z Aurigæ	5	53	39	+ 53	18.0	+ 4.86	+ 0.01
20.1903	W Camelopardalis	6	12	0	+ 75	32	+ 8.25	− 0.02
14.1903	RS Geminorum	6	55	14	+ 30	39.8	+ 3.84	− 0.08
9.1903	Z Geminorum	7	1	36	+ 22	41.0	+ 3.61	− 0.09
16.1903	RR Monocerotis	7	12	27	+ 1	16.6	+ 3.10	− 0.10
13.1903	RR Geminorum	7	15	11	+ 31	4.2	+ 3.83	− 0,10
21.1903	Y Camelopardalis	7	27	39	+ 76	16.9	+ 8.15	− 0.12
4.1902	Y Geminorum	7	35	16	+ 20	39.6	+ 3.53	− 0.13
2.1903	Y Draconis	9	31	5	+ 78	18.2	+ 6.98	− 0.27
3.1903	W Ursæ Maj.	9	36	44	+ 56	24.6	+ 4.25	− 0.27
4.1903	Z Draconis	11	39	49	+ 72	49.0	+ 3.45	− 0.33
57.1903	T Ursæ Min.	13	32	38	+ 73	56.4	+ 1.25	− 0.31
29.1903	ST Herculis	15	47	47	+ 48	47.1	+ 1.79	− 0.18
18.1902	W Coronæ	16	11	50	+ 38	2.7	+ 2.14	− 0.15
31.1903	SU Herculis	17	44	42	+ 22	34	+ 2.52	− 0.02
76.1901	RT Ophiuchi	17	51	51	+ 11	10.9	+ 2.81	− 0.01
19.1903	RZ Lyræ	18	39	54	+ 32	41.7	+ 2.23	+ 0.06
17.1903	RY Lyræ	18	41	15	+ 34	34.0	+ 2.17	+ 0.06
17.1902	RW Lyræ	18	42	7	+ 43	31.9	+ 1.82	+ 0.06
10.1903	RX Lyræ	18	50	27	+ 32	42.3	+ 2.23	+ 0.07
55.1903	VW Cygni	20	11	21	+ 34	11.8	+ 2.31	+ 0.18
21.1902	V Sagittæ	20	15	46	+ 20	47.3	+ 2.65	+ 0.19
16.1902	Z Delphini	20	28	3	+ 17	6.2	+ 2.74	+ 0.20

* From Supplement to Nos. 549-550 of the *Astronomical Journal.*

Nomenclature of Newly Discovered Variable Stars.—Continued.

Provis. Notation A. N.	Name.	Position for 1900.0 R. A. h m s	Decl. ° ′	Prec. 1900 R. A. s	Decl. ′
15.1902	Y Delphini	20 36 52	+ 11 30.9	+ 2.86	+ 0.21
58.1903	VX Cygni	20 53 34	+ 39 47.5	+ 2.26	+ 0.23
20.1902	VV Cygni	21 2 20	+ 45 22.6	+ 2.12	+ 0.24
19.1902	RT Pegasi	21 59 49	+ 34 38.2	+ 2.61	+ 0.29
	RS Andromedæ	23 50 19	+ 48 4.9	+ 3.01	+ 0.33
12.1903	Nova Geminorum	6 37 49	+ 30 2.6	+ 3.83	— 0.05

Nomenclature of Newly Discovered Variable Stars.—Continued.

Provis. Notation A. N.	Name.	Chart-Place. R. A. h m s	Decl. ° ′	Magnitude. Max.	Min.	
11.1903	RU Andromedæ	1 30 11	+ 37 55.6	9	13	*ph*
15.1903	Z Cephei	2 7 6	81 0	9.10	< 13	*ph*
56.1903	RR Cephei	2 24 15	80 30.2	9	< 13	*ph*
14.1902	Z Persei	2 30 50	41 34.3	9	12	*v*
22.1903	X Camelopardalis	4 26 48	74 50	9	13	*ph*
5.1903	RS Tauri	5 43 28	15 50.3	8.9	10.11	*v*
1.1903	Z Aurigæ	5 50 3	53 16.9	9	11	*v*
20.1903	W Camelopardalis	6 5 48	75 32	10.11	12	*ph*
14.1903	RS Geminorum	6 52 21	30 43.3	9.10	11.12	*ph*
9.1903	Z Geminorum	6 58 53	22 44.9	9.10	< 12	*v*
16.1903	RR Monocerotis	7 10 7	1 21.2	9	< 13	*ph*
13.1903	RR Geminorum	7 12 18	31 9.0	10	11.12	*ph*
21.1903	Y Camelopardalis	7 21 30	76 22.3	9.10	< 11.12	*ph*
4.1902	Y Geminorum	7 32 37	20 45.3	8.9		*ph*
2.1903	Y Draconis	9 25 47	78 30.1	9	13	*ph*
3.1903	W Ursæ Maj.	9 33 32	56 36.7	8	9	*v*
4.1903	Z Draconis	11 37 12	73 4.0	9.10	12.13	*ph*
57.1903	T Ursæ Min.	13 31 42	74 10.2	9	< 13	*ph*
29.1903	ST Herculis	15 46 27	48 55.4	7.8	8.9	*v*
18.1902	W Coronæ	16 10 14	38 9.6	7.8	13	*v*
31.1903	SU Herculis	17 42 48	22 35	10	< 12	*ph*
76.1901	RT Ophiuchi	17 49 45	11 11.5	9	< 10	*v*
19.1903	RZ Lyræ	18 38 14	32 39.1	10	11.12	*ph*
17.1903	RY Lyræ	18 39 38	34 31.4	10	12	*ph*
17.1902	RW Lyræ	18 40 45	43 29.2	9	< 12	*ph*
10.1903	RX Lyræ	18 48 46	32 39.0	11	< 15	*ph*
55.1903	VW Cygni	20 9 37	34 3.7	9.10	11.12	*ph*
21.1902	V Sagittæ	20 13 47	20 39.0	9.10	13	*ph*
16.1602	Z Delphini	20 26 0	16 57.2	9	< 11	*ph*
15.1902	Y Delphini	20 34 43	11 21.5	9.10	< 13	*v*
58.1903	VX Cygni	20 51 52	39 37 2	9	9.10	*ph*
20.1902	VV Cygni	21 0 45	45 11.9	11	< 12	*ph*
19.1902	RT Pegasi	21 57 51	34 25.3	9.10	13.14	*v*
	RS Andromedæ	23 48 4	47 49.5	7.8	8.9	*ph*
12.1903	Nova Geminorum	6 34 56	+ 30 5.0	5	—	—

The committee for the A. G. Catalogue of Variable stars: Dunér, Hartwig, Müller, Oudemans.

New Variable Star 61.1903 Cygni.—In *A. N.* 3915 Mr. A. Stanley Williams announces this new variable, which is

BD + 39°4423 (9.5), R. A. = $20^h\ 58^m\ 42^s.9$; Decl. = + 39° 23′.7 (1855)

The range of variation is from about $8^m.8$ at maximum to $9^m.5$ at minimum in a period of 7.857 days. From minimum to maximum the interval is 2.1 days, and from maximum to minimum 5.76 days. Future maxima should occur Jan. 9.24, 17.09, 24.95, Feb. 1.81, 8.66, 16.52, 24.38 Greenwich civil time.

Maxima of U Pegasi.

Period $4^h\ 29^m.8$. The minimum occurs $2^h\ 15^m$ after the maximum.

	d	h		d	h		d	h		d	h
Feb.	1	13	Feb.	9	14	Feb.	17	16	Feb.	25	12
	2	16		10	13		18	14		26	15
	3	14		11	16		19	13		27	14
	4	13		12	14		20	16		28	12
	5	16		13	13		21	14		29	15
	6	14		14	16		22	13			
	7	13		15	14		23	15			
	8	16		16	13		24	14			

Maxima of Y Lyræ.

Period $12^h\ 03.9^m$.

	d	h		d	h		d	h		d	h
Feb.	1	19	Feb.	8	19	Feb.	15	20	Feb.	23	21
	2	19		9	20		16	20		24	21
	3	19		10	20		17	21		25	22
	4	19		11	20		18	21		26	22
	5	19		12	20		19	21		27	22
	6	19		13	20		20	21		28	32
	7	19		14	20		22	21		29	22

Maxima of UY Cygni.

Period $13^h\ 27^m\ 21^s$. The minimum occurs $1^h\ 53^m$ before the maximum.

	d	h		d	h		d	h		d	h
Feb.	1	15	Feb.	9	11	Feb.	17	8	Feb.	25	4
	2	18		10	14		18	11		26	7
	3	21		11	17		19	14		27	10
	5	0		12	20		20	16		28	13
	6	3		13	23		21	19		29	16
	7	6		15	2		22	22			
	8	8		16	5		24	1			

GENERAL NOTES.

This number indicates the beginning of changes in the plan and management of this magazine to which reference has already been made. The plan now unfolding has been a cherished one for a long time past, its fulfillment being possible because of favoring circumstances we can now control. These consist mainly in better office facilities, better and more ready printing, finer engraving, ample assistance for translations, and, most important of all, largely increased help in securing original articles to set forth, month by month, the condition and progress of astronomy in general and American astronomy in particular.

In this broader plan it is not our aim to seek an international prominence, or a purely professional cast of detailed methods of astronomy work, but, rather to confine our efforts to work in the home field to relate it, and to unify it more closely and effectively for all interested or even remotely concerned. If it should be possible to unite only a small part of the available energy, now largely unused in this way, in the different parts of the United States, who can measure the ample results of such coöperation for the benefits of astronomy in numberless ways. In this worthy endeavor we hope for the ready response of very many to our appeal for such assistance as may be easily rendered because it is only the little that will be asked of the many.

From the beginning we have endeavored to keep the subscription price of this magazine lower than any other of its kind and size to be found anywhere as far as we know. Because writers have furnished articles free of charge, and because we have had our own office and have given our time to this work without financial return, we have been able always to meet expenses and pay cash in advance for needed annual supplies. Whether this can be done in the future without an increase in the subscription price remains to be proved. It can be done if the merit of the publication is what it should be, and interest in its support is sufficiently general.

Auroral Band.—In a recent letter from Dr. D. L. Stewart, of the Cincinnati Observatory is given an account presumably of the Auroral band which was so generally observed in August last. The statement in the words of the observer was as follows:

"There appeared in the sky overhead at the resort of Omena on Great Traverse Bay, Mich., one evening in August what was a mystery to common observers. It extended S. S. E., where it seemed to touch the horizon across the bay, and in a straight line directly overhead reaching in the opposite direction, to within forty or fifty degrees of the horizon. To the naked eye it appeared to be more distant than high clouds.

It seemed to be brighter or denser along the center line of it, and was, I should think, one degree in width, or two at most. When I first saw it, the width was the same throughout its entire length, with the exception of the visible end which tapered abruptly and faded.

The time of night was between nine and ten o'clock P. M. Its duration was ten or twenty minutes after I saw it. It became gradually shorter and narrower, the south-eastern end also appearing and then receding slowly from the horizon, during which time its brightness was diminishing.

Just before it faded out, it assumed a blotched appearance after which it was quickly gone. When its light was strongest, it was brighter than the Milky Way, but I saw no color."

Auroral Band, Lincoln, Ill.—At first, not long after dark, a faint, narrow, irregular streak of light shot up from the eastern horizon, gradually becoming brighter till it nearly reached the zenith, when a similar appearance showed in the west, till the two met, overhead, forming a band from horizon to horizon, through the zenith, white and well-defined, and perhaps five degrees wide. At its brightest there was a wavy, cloud-like motion from east to west like drifting clouds of thin steam. This band was, perhaps, an hour in forming, and as long in completely disappearing, a short time after which, a slight streak appeared again in the east, but soon vanished.

The band in forming moved a little to the south of its first position, in the east. An Aurora was visible all the time in the north, and increased in brilliancy after the band disappeared. No disturbance was noticed in the railroad electric instruments.

This phenomenon seems to have extended from Montana to Maine. It would be of interest to know if it extended around the world. O. A. ALLEN

LINCOLN, ILL.

Aug. 21, 1903.

The Solar Activity.—From October last the Sun has begun to show great activity. No doubt the time of maximum is approaching. The lovers of astronomy have now a good opportunity to direct their attention to the Sun.

I observe the Sun every morning, at seven, and I keep a collection of drawings of my observations, which drawings are useful in comparing old and new spots.

November last was a good month for solar observations; not a single day was the Sun without spots and there were some very fine groups. December has also shown great activity on the Sun and the indications are that it will continue. On the first day of December appeared one new spot on the south-east limb,

and all around it there were great and brilliant faculæ. There were also visible two large spots north and a group south.

On the second day two new spots made their appearance at the same limb. On this day one of the large spots of the north had the shape of a heart. On the third day the two new spots of the day before had developed considerably. The south-east group was magnificent on the fifth day.

Sunday sixth, appeared one new spot on the north-east limb. I must say that this spot I observed at 4 o'clock in the afternoon; in the morning nothing was visible on that region. Monday 7th, another new spot showed at the same region. On Thursday 10th, I noticed a new and fine spot at the south-east limb. The faculæ on this region were indeed unusually large. On the 11th, 12th, and 13th my attention was specially directed to the two large sun-spots which appeared on the 6th and 7th. They are large with the penumbra perfectly defined and the filaments of a grayish color. The faculæ have been specially large and brilliant these days. LUIS G. LEON.

MEXICO.

December 13th, 1903.

The Terminator of Venus.—While observing Venus on Nov. 21st at 7:30 A. M. in a clear and serene sky, very distinct markings, curvilinear in form, and extending well towards the periphery of the disc were clearly seen, resembling in a general way those seen on the lunar surface to unassisted vision, the accompanying sketch giving the approximate location; this is my first opportunity of seeing more than the usual irregular terminator with its dark shading. The image was steady and beautifully defined, but a subsequent observation perhaps 30 minutes later, found the disc a moving mass with no detail. The instrument used was a reflector by Mr. Brashear, with 8½-inch speculum. WESTON WETHERBEE.

VENUS, NOV. 21, 1903.

BARRE, N. Y., Nov. 27, 1903.

Leonids at Providence, R. I.—At the Ladd Observatory, observations were planned for November 13, 14 and 15 (astronomical reckoning). The first of these nights was wholly cloudy and the last partly overcast, but the second was beautifully clear. The sky east of the meridian was carefully watched from 13^h to 17^h, especial attention being given to the region within 30° of Leo. The total count by two observers was 20 Leonids and 24 other meteors. Eighteen of the former were charted, and were well distributed in all directions from the radiant point. The position of the radiant point determined from them is R. A. $10^h\ 1^m$, Decl. + 21° 48′. In 1901, on the corresponding night (November 14, $12^h.35 - 17^h.30$), 91 were charted. In 1902, cloudy weather prevailed. The small number observed this year was not due to unfavorable conditions, but shows that few entered the atmosphere within the region of observation.

PROVIDENCE, R. I. November 24, 1903. W. UPTON.

Approach of Sunspot Maximum.—During the month of July we observed at Wake Forest, N. C., as many as ninety sunspots—part of them north of the solar equator, and part south, as illustrated in "Sunspots in July" in the August number of POPULAR ASTRONOMY. No such persistence and rapid succession of

spots and groups has occurred in the past five or six years. They were certainly heralds of an approaching sunspot maximum. These numerous July spots were indeed all relatively quite small. And size, as well as number, is an element in such a maximum. This element of size, however, has already begun to change. In October a very large group of spots darkened the Sun's disk. Using a shield of smoked glass it could be seen with the naked eye. When first observed here, at noon Oct. 14th, it was larger than any group seen since 1892. By the 18th of October it reached the Sun's western limb and passed out of view. But in due time, it reappeared to us on the Sun's eastern edge. It was there in full view when observed in the early morning of Oct. 30th, but its form was altered. Early in the month it was somewhat rectangular in shape. Its vast extent excited general interest. As estimated by good authorities it was 120,000 miles long and 40,000 miles broad. That is, it covered an area more than 24 times the entire surface of our Earth.

When seen again at Wake Forest, Oct. 30, it had divided into three great spots. Nov. 3, when well advanced into view, it was still more changed. One spot had almost closed, each of the other two had expanded, and grouped about them were 18 relatively small spots.

With like mutations it remained a conspicuous object until Nov. 12, when it again passed the Sun's western edge out of view.

Meanwhile, two other extensive groups appeared. The first of these was observed Oct. 26, just as it rounded the Sun's eastern limb. It was somewhat triangular in shape, and about one-third the size of the great group which has now twice passed the western limb of the Sun. Varying in aspect from day to day, it too passed the western limb Nov. 7.

The other group, the third in order of these extensive disturbances, was seen near the east limb Nov. 4. Next day, when more fully in view, it showed four very large spots, with fifteen smaller ones clustered about them. Its area exceeded that of its immediate predecessor, and its changes of form were more surprising. It passed out of view about Nov. 16.

These three great groups, in view within a month, together exceeded in extent forty times the entire surface of our Earth. They amply furnish the element of size, as the July sunspots gave that of number. Number and size indicate growing solar disturbance, and evidence unmistakably an approaching sunspot maximum.

The period from one maximum to the next being about eleven years, we may expect the one now approaching to culminate in or near the year 1904. It is a favorable time for the study of interesting questions touching solar conditions. I make a single suggestion as to the nature of sunspots.

They are often referred to as furious solar storms or cyclones. Unquestionably, in spot areas the surface material is tossed and torn asunder—and adjacent glistening faculæ consist of solar matter thrown into widely irregular masses piled many times mountain high.

But can there be at the Sun's fiercely hot surface any such differences of temperature as are essential to movements in anywise analogous to storms terrestrial?

Moreover, we note on the Sun a fairly sharp boundary between the dark disturbed areas and the adjoining bright regions; while on our Earth there is always a gradual transition from regions of storm to regions of calm. Again, storms sweep the Earth's surface, while motion in sunspots, or seeming motion, is

mainly vertical. Such considerations tend to the view that sunspots are formed by internal, uprushing energy, rather than by surface, storm-like action.

In either view allowing remoteness of resemblance, may we not liken sunspots to our earthquakes, rather than to our wind storms? Is it objected that a sunspot covers a great area, and often persists for weeks or months? True, our earthquakes usually produce *visible* results only in small areas, and quickly subside; but often they are *felt* throughout an extensive territory.

The recent earthquake, Nov. 4, which caused consternation in the city of St. Louis, was felt in eight states—Missouri, Illinois, Indiana, Kentucky, Tennessee, Mississippi, Louisiana and Arkansas. An earthquake in the year 357 A. D., in that ill fated region which we now know as politically convulsed Macedonia, was so widespread that it swallowed up 150 cities. The great earthquake of 1755 which destroyed Lisbon with its 50,000 people, destroyed or damaged several other cities of Portugal and some in Spain and in Morocco, and extended its disasters east to Arabia and west to the island of Madeira. In 394 A. D., an earthquake in Europe wrought its destruction of city after city for fully one month; and one in Constantinople in the year 480 A. D. convulsed that region for forty days.

In point of fact, then, as regards both extent and duration there is analogy between the sunspot and the earthquake. From these several considerations—probable uniform temperature, sharpness of demarkation, seeming preponderance of vertical motion, and analogy in extent and duration—we may say the spots are in no sense solar surface storms, but rather deep seated solar disturbances.

As shown, the first great sunspot in October was of vast extent and displayed its vigor for more than a month. The sunspot maximum now at hand promises abundant opportunity for noting other such outbursts of solar energy, some perhaps on a still grander scale. J. F. LANNEAU.

Is the Universe Limited in Extent and Spherical in Form?—We have received a communication from a very intelligent and thoughtful reader of this publication in regard to the open question of the extent and form of the material universe. Our correspondent is evidently not satisfied with the positions taken by Mr. Wallace, in our last October number, whose arguments therein tended to show that our universe is both limited in extent and spherical in form. The objections offered are:

1. The mind can form no conception of anything infinite.

This statement is too broad. Since the time of Newton especially mathematicians have dealt with infinities and infinitessimals as easily and certainly as with finites through the methods of the Calculus. They must know much about infinities or they would know less about finites.

2. The boundary between the finite and the infinite is a barrier the human mind cannot cross.

If our correspondent means a hard and fast line somewhere in the realm of physical reality, he may be right. But this is not the sense in which the scholars in mathematics speak of the limits of the finite and of the infinite. The mathematician will pass from the finite, over its limits, into the infinite just as easily as a lawyer will pass from one point in his brief to another which is a definite and a logical sequence in the course of his reasoning.

3. Is space filled with matter and force or only partly filled?

Our correspondent thinks that if space is only partly filled (as Mr. Wallace contends in the article above referred to) by a finite material system of stars, it will follow as a necessary consequence, that this finite system must have a center of gravity somewhere, and that if the force of gravity extends throughout this universe, all matter must tend to this center, and be in a state of condensation towards it, unless a dynamic equilibrium is maintained by some force opposed to gravity. So far as we know this equilibrium of all bodies is maintained by a motion of revolution or rotation. The imaginary spherical universe must then either revolve around its own center of gravity or rush to ruin on its center. So far as we know it is doing neither.

The above statement is nearly in our correspondent's own language, and in the main is good reasoning from known facts, as far as it goes. He doubtless knows "That the mills of the gods grind slowly, but they grind exceeding fine." The whole difficulty in framing decisive argument, in such great questions as these, is, the lack of data for generalization in theory or presumptive inference. Our real data have scarcely yet reached the stage of more than plausible inference. We can not certainly say whether or not the universe is limited. From the behavior of comets and new stars, so called, we know something of the startling possibilities of matter, ether force, and motion; but we need to know more before we can claim knowledge of more than plausible inferences regarding the extent and form of the great physical universe.

The Stellar Heavens by J. Ellard Gore. F. R. A. S., is a new book published by Chatto & Windus of 111 St. Martin's Lane, London, W. C. England. It is an introduction to the study of the stars and nebulæ; or that part of sidereal astronomy which deals with the number, motions, distances, etc., of these two classes of celestial objects. In a small book of 128 pages, the descriptions and the details only of the more prominent and interesting stars and nebulæ could be given; and the information furnished is brought up to date, and is useful both to beginners, as well as to the more advanced students of the stellar universe.

The contents of the book is divided into five chapters, with the following order of topics: The stars; double, multiple, and binary stars; variable stars; star clusters and nebulæ, and the stellar universe. Under the first topic, the stars, the author speaks of the constellations historically and critically with leading facts in detail, supplemented by notes from the appendix. He places the total number of the stars visible in the largest telescopes at "probably about 100,000,000." In this connection is found an interesting paragraph or two relating to the number of stars found in old and new catalogues and atlases of the stars; especially that estimate from Herschel star guages at a total of 200,000,000, or another from the richness of the Galaxy 82,000,000, or, from a spot near Cygnus in the Galaxy taken by Dr. Roberts in 1898, showing 30,000 stars in the space of three and a half square degrees. That would mean a total of 360,000,000. But when photographs are taken near the poles of the Galaxy, the number falls off with surprising rapidity. One such shows only about 7,500,000. The first named estimate is probably a safe one.

Star magnitudes and star colors have, in late years, claimed most thorough attention in standard stellar work, because so much in the investigation of vari-

able stars depends on a correct knowledge of magnitudes; and because changes in color suggest possible changes in physical conditions that will be followed with the utmost care. The stellar magnitude of the Sun gives an example of other interesting data of the same kind. It is stated on page 7, that "various estimates of its value have been made ranging from —26 to —27, and it may be taken at about —26.5 (or about 8,954,000,000 times brighter than Sirius)" the most brilliant star in the whole heavens.

In regard to the spectra of the stars Vogel's classification is followed, but in the tables of the few stars given, the parallax and distances are credited to Yale University Observatory. This list embraces such stars as Arcturus, Vega, Capella, Procyon, Altair, α Orionis, Aldebraran, Pollux, α Cygni and Regulus. It does not seem possible that some of the brightest stars in the heavens are so far away that it requires over 300 years for their light to reach us. The author mentions Rigel as such a bright star in Orion on the authority of Sir David Gill. This important fact was generally noticed when it was published by that careful student of stellar parallax.

The absolute size of the stars, their proper motions, and the Sun's motion in space are the remaining topics found in the first chapter. Two interesting conclusions are noticed at its close; one is the close agreement of Professor Campbell's work on the velocity of the Sun through space which gave a result of 12⅓ miles, with that of Professor Kapteyn which came out as 11.44 miles per second. That means that our Sun with all his system of planets moves annually, in space, about four times the Earth's mean distance from the Sun. The other probable fact, still more surprising, if possible, is the work of Eberhard, Keeler and Vogel who found that the great nebula of Orion is receding from the Earth, at the rate of 10.85 miles per second, nearly in the opposite direction from that in which the Sun is moving.

The notice of this first chapter of this book is not presented so fully because it is more worthy than others, but, for the purpose of giving our readers some definite ideas of the general make-up of the work. The second chapter on double, multiple and binary stars is full, apparently exact; and even strong on spectroscopic binaries for so small a book. But the chapter on variable stars is the strongest of all, probably because there is so much of recent knowledge in this new branch of astronomy that to do it justice, nothing less ought to have been done.

The final chapter which is concerned with the Milky Way, the Stellar Universe, and the Nebular Hypothesis is a comparatively brief one consisting of twelve pages. Having been so much interested in these great themes ourselves in recent years, the brief treatment of them here is a little disappointing. Yet not much stress can be justly laid on this, because in this field is the border land of modern study, and much of conjecture prevails in almost everything we know about it.

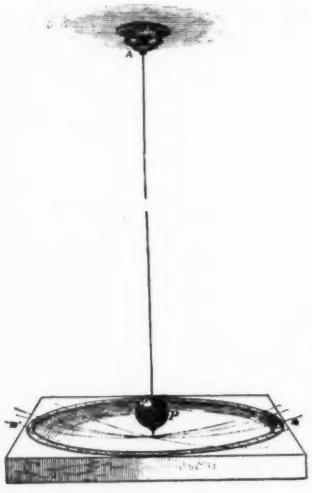
The dozen pages of the appendix and index fittingly closes this volume, that, though unpretentious, fully deserves the favorable notice here given it.

Visible Proof of the Earth's Rotation.—The experiment to which attention is here called usually goes by the name of the Foucault Pendulum Experiment. It is not new, but whenever or wherever tried it always elicits great interest in the minds of the most scholarly, as well as the commonly intelligent

observer who can easily understand its meaning with a brief explanation. We call attention to it now, because we have some things to say about it that may awaken new interest in the experiment if they are not entirely new to all our readers.

This visible proof of the Earth's rotation on its axis was first shown in Paris in 1851, by an ingenious French physicist by the name of Foucault. The Pantheon was the place chosen for the experiment. From the dome of that building, he suspended an iron ball one foot in diameter, by a wire more than two hundred feet long. The ball was drawn to one side and fastened with a cotton cord, and it was held in that position until it came to absolute rest. The cord was burned off and the ball began to swing like a great pendulum and it continued to do so for hours after it was freed.

This same experiment on a small scale was recently tried in the Chapel of Carleton College at Northfield before the Junior class in college astronomy, and some other invited guests. An iron ball weighing one hundred pounds was suspended by a fine piano wire from the ceiling of the Chapel a height of about thirty feet, drawn aside and tied back until it was at rest as above indicated. It was freed by burning the cord and the vibration began in a line almost exactly north and south. The vibrations of this long pendulum were watched for one hour.



Very soon after its swing began it was easily seen that the north end of the vibration turned to the east, and the south end to the west. It seemed to the observers that the direction of the swing of the pendulum was turning around with reference to the floor and the building and the points of compass, and that was exactly the fact. The accompanying illustration makes plain to the eye what is seen generally when the experiment is carefully performed. The right hand side of the cut is south. If the swing of the ball had been kept up continuously for thirty-two hours it would have turned completely around. The above cut is taken from Young's General Astronomy.

If the experiment could be tried at the poles of the Earth, and the plane of the vibration of the pendulum should not change with reference to a star, it is easy to see that the Earth would really turn around under it in just twenty-four hours. For the same reason at the Earth's Equator it would never complete a revolution. If a person could stand at the North Pole and watch such a pendulum for a whole day, the swing of it would seem to be turning around as just described, instead of the motion of the Earth in a contrary direction. What the pendulum appears to do, the Earth really does. It therefore illustrates the real motion of the Earth on its axis very exactly and very satisfactorily. Since there is no turning of the swing of the pendulum at the Equator of the Earth, and a complete rotation at the Poles in twenty-four hours, it is evident that the time of its rotation will increase from the Poles to the Equator, and depend really on the latitude of the place where the experiment is tried. In the latitude of Northfield the time is about thirty-two hours as said above.

The results of this experiment were not entirely satisfactory, because the apparent change in the plane of vibration per hour was too great. In every trial made the same error appeared in the same way with a single exception. The cause of the error was the fact that the ball did not keep its swing constantly in a vertical plane. During the last half hour, it was evident that it was swinging in a long and very narrow ellipse, clockwise, as it should go to increase the angular shift of the vertical plane of motion. It was probably disturbed either by not having come to absolute rest before it was freed, or later by air currents due to the movement of visitors too near to it. The experiment will be tried again with improved suspension apparatus and a magnetic attachment to keep the amplitude of the vibration as nearly a constant quantity as possible, during any length of time desired for the trial. When this very delicate experiment is successfully performed it ought also to show the latitude of the place very closely.

A Novel Observatory.—Herewith we present a cut of a residence with a novel Observatory attached. It is the property of an interested student of astronomy, Mr. C. F. Harms, of Brooklyn, N. Y. From a description, in a private letter, we give the following facts, in his own words, which may interest students of astronomy and be suggestive to amateur observers:

Given a round superstructure (or square or octagonal, for that matter), a revolving dome like mine, of fourteen (14) feet diameter, answering all reasonable demands, can be constructed for about three hundred dollars.

A wooden circular plate, 3″ x 5″, made of 1½″ x 5″ pine sections, doubled and overlapped, is fastened to the studdings of the tower and the outside sheathing boards are nailed to it, so as to project 2″ above the same. This forms a bed for 2½″ x 2″ x ¼″ angle iron, which I had bent in a true circle at a machine shop, and provided with a lot of countersunk holes for fastening with 3″ screws. For convenience of handling, it was made in four pieces, and fitted to a nicety. The 2½″ side forms the base. Another circular wooden plate, about 3″ x 6″ (1″ wider), was provided also with a circle of angle iron, but reversed, the 2½″ side of the iron being fastened to it. This latter wooden circle forms the base for the dome rafters, and the angle irons form the runway for exactly 2″ steel or cast iron balls, on the live ring principle.

A little thought will show that there is no lateral motion to speak of, and if well oiled, the tower works with slight effort. To fill the runway with steel balls, would be quite expensive, as they cost about seven dollars per dozen. I only used

thirty-six (36) of these steel balls, and procured nine dozen glass balls, of ⅛″ less diameter, which latter can be bought for a nominal amount, and distributed them between the steel balls. They tend to prevent them from running together on one side, and answer the purpose very well, absolutely not carrying any weight.

I feel quite proud of my achievement, and if anyone should desire to imitate it, will be pleased to furnish further details which have not been mentioned in this article.

At Sea Gate, Brooklyn, N. Y.

I consider this construction far superior to hinged roof arrangements, and certainly of more pleasing aspect, more satisfactory in high winds, more protective against the elements, at about the same cost.

I must add a brief description of my shutter, which also works very satisfactorily. The opening is 2′ 3″ wide, and the shutter rests on a frame similar to a large scuttle of a roof, but with the lower part of cross frame left out. There are a number of so-called sash rollers let in on the longitudinal frame, for it to roll on, and is worked with a small pulley. Two ribs or frames spread about 2″ more than those that the shutter rests on, and also provided with a number of these little rollers, are fastened on the opposite side of the roof, and guide the shutter on its travel. The cross boards of the shutter, overlap 2″ on each side. I hope that I have made this plain enough-

The rafters of the roof, of course, are sections of a true circle, made out of 1¼″ x 4″ pine, doubled and overlapped, and sheathed with narrow ¼″ ceiling boards, laid diagonally on the four quarters of the roof, and the whole is covered with canvas, and well painted. A double thickness of this canvas lapping over the side, nearly touching the tin gutter, forming a perfect protection against rain and snow. The distance from the floor to the opening is six feet. I have room enough to comfortably work with my 8″ equatorial (Henry Fitz lens), of 9′ focus, mounted on iron pillar, to which I have lately attached a driving clock, furnished by Mogey Bros., of Bayonne, N. J., and working very satisfactorily; also find room for a small desk, sextant camera, shelves for books, and other small attachments; a sidereal clock, and a small but exceedingly well constructed transit in the south window.

The room is painted a dead black. The inside of the dome, I have covered with heavy black cardboard, and this offers a tempting surface for decoration with astronomical subjects, on which I am at work at present, drawing them on black cloth with white ink, and pasting them on the cardboard. Beginning at the bottom, the first 3′ 6″ are covered with twelve different aspects of the heavens, for every 2^h of R. A. Above this comes the zodiacal belt, each constellation 3′ x 2′ above which circles the yearly calendar showing the daily position of the Sun. The rest of the space will show the planets in their different orbits, and of proportionate distance and size from the Sun, in the center (apex of the dome). This is commencing to look quite imposing; to me at least.

On the floor of the room, I am trying to locate the noon mark of the Sun daily on a meridian line, the former shining through a good sized pin hole, three feet up on the dome. This is not a success, as far as I can yet see.

BROOKLYN, N. Y., Nov. 5, 1903. C. F. HARMS.

Radium and the Sun's Heat.—In your last week's issue Mr. Hardy directs attention to the fact that no Becquerel rays can be detected from the Sun, and regards this as an objection to the view that the solar heat may be accounted for by the presence of radium.

Let us attempt to calculate the effect to be expected if the Sun's heat were due to this cause.

In doing this, we may assume that the Sun contains 3.6 grams of radium per cubic meter. This was the amount which Mr. W. E. Wilson gave in *Nature* of July 9 as required to emit the observed amount of heat. Experiment shows that when the Becquerel radiation has to pass through lead screens of thickness 1cm. or more, the radiation transmitted is practically all of the γ variety. This is cut down to half its value by 8cm. of aluminium, and in the case of other substances by strata of equal mass per unit area. Now the Earth's atmosphere constitutes a stratum far more absorbent than 1 cm. of lead. We need, therefore, only consider the γ rays, for if these cannot be detected, it is certain that the α and β rays cannot.

For the sake of simplicity of calculation, we shall treat the Sun as a cube, with its side equal to the diameter of the real Sun, and so placed that the normal to one face, which passes through the centre, shall also pass through the Earth. This will be for all practical purposes near enough to the truth.

Let a be the side of the cube, q the quantity of radium per c.c. and λ the coefficient of absorption of the radiation. Then, from an elementary slice, thickness dx, and distance x from the face, the intensity of radiation at a distant point will be

$$a^2 q e^{-\lambda x} dx$$

if the radiation due to 1 gram of pure radium at the same (great) distance be taken as unity.

The radiation due to the entire mass will be

$$a^2 q \int_0^a e^{-\lambda x}\, dx = a^2 q \left[\frac{-e^{-\lambda x}}{\lambda} \right]_0^a = \frac{a^2 q}{\lambda} \left(1 - e^{-\lambda a} \right)$$

Now $a = 1.4 \times 10^{11}$ cm.; q, from Mr. Wilson's estimate $= 3.6 \times 10^{-6}$.

Assuming that the coefficient of absorption is proportional to the density and taking the Sun's density as 1/7, and the value of λ for aluminium as 0.086, the value of λ for the Sun comes out 0.0046. Substituting these values, we find that the effect of the Sun is equivalent to that of 1.53×10^{19} grs. of radium at the same distance, assuming this radium to be spread out into a thin layer, so that all the radiation can escape without undergoing absorption in the mass.

Now I have found that the γ radiation from 10 milligrams of radium bromide can barely be detected by the electrical method, where 10 cm. of lead intervene between it and the testing vessel. To decide whether the solar rays would be detectable, we must compare their expected effect after enfeeblement by distance, and by the absorption of the atmosphere, with this.

The distance of the Sun is 1.5×10^{12} times greater than the distance of the radium from the testing apparatus, so that, apart from the atmospheric absorption, the effect of the Sun would be equivalent to that of $\frac{1.5 \times 10^{19}}{(1.5)^2 \times 10^{24}}$, or 67×10^{-6} grams of radium, 10 cm. from the apparatus. This is less than one-thousandth part of the radium used in the experiment cited, and the solar radiation, instead of passing through only 10 cm. of lead, would have to pass through the atmosphere, equal in mass to 32 feet of water, or about 89 cm. of lead. This would, of course, reduce it many million times further. So that, even if all the Sun's heat were due to radium, there does not appear to be the smallest possibility that the Becquerel radiation from it could ever be detected at the Earth's surface.

R. J. STRUTT.

Nature, October 15, 1903.

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WM. W. PAYNE,
Northfield, Minn., U. S A.